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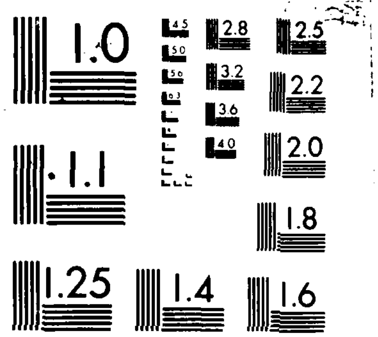

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An Investigation Conducted By
Western Instrument Corporation
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NCEL
Contract Report

AD-A176 878

INSPECTION FREQUENCY CRITERIA MODELS FOR TIMBER, STEEL, AND CONCRETE PILE SUPPORTED WATERFRONT STRUCTURES

ABSTRACT The Navy has no specific criteria for establishing the time interval between successive waterfront inspections or for determining the priority of waterfront facilities to be inspected. This report presents the strategy used to develop a preliminary inspection frequency model and the requirements needed to determine the order of inspections. The criteria used for determining when inspections should be performed were: construction material, facility age, present condition, facility environment, and mission requirements. A database was designed for searching, sorting, and correlating inspection data for determining the best time interval between inspections while maintaining safe and operational structures.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043

METRIC CONVERSION FACTORS

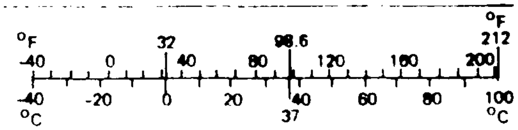
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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The Navy has no specific criteria for establishing the time interval between successive waterfront inspections or for determining the priority of waterfront facilities to be inspected. This report presents the strategy used to develop a preliminary inspection frequency model and the requirements needed to determine the order of inspections. The criteria

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used for determining when inspections should be performed were: construction material, facility age, present condition, facility environment, and mission requirements. A database was designed for searching, sorting, and correlating inspection data for determining the best time interval between inspections while maintaining safe and operational structures.

CONTENTS

EXECUTIVE SUMMARY

The inspection of timber, steel, and concrete waterfront structures is of major importance to the Navy. More than two-thirds of all Naval waterfront facilities are over 40 years old. Natural deterioration of piles occurs over time and inspections of aging facilities help to identify those pile elements that may be subject to failure. The purpose of developing an inspection frequency strategy is to optimize the time between inspections in order to avoid unnecessary expenditures without interrupting current operational status.

At the present time, the Navy inspects and maintains hundreds of waterfront facilities. Inspection and maintenance data are collected in FPO-1 reports, copies of which are located at the Naval Civil Engineering Laboratory. As the data become available, it is electronically digitized and stored in a computerized inspection data base for easier access and analyses.

A number of statistical procedures were implemented to estimate the rate of deterioration in timber, steel, and concrete piles. Principal among these were multiple linear regression and logistic regression. Information obtained from the inspection data base were used to generate the deterioration rates. Inspection frequencies were subsequently proposed and used in computer software developed specifically for this project. A User Data Package (UDP) that incorporates the frequency recommendations has been prepared for general guidance in the field by inspection teams. Examples of the computer runs are provided for facilities supported by piles made from each material type. The frequency inspection listings provide estimates of total costs incurred for inspection, repair and replacement of the piles. The lowest total costs for a given year represent the year in which an inspection should take place. The listings will vary from facility to facility as different input values are entered into the inspection frequency program. Thus, the program can be used for any facility for which adequate data are avilable.

It is recommended that the procedures developed and described herein be continued in an effort to achieve more accurate estimates of the rates of deterioration. It is also recommended that the inspection data file be periodically updated as new inspection data are obtained.

INTRODUCTION

The effect of harsh environmental conditions on waterfront structures is well documented (Ref 1-3). As a result, deterioration of timber, steel and concrete piles over time is a major concern. The Navy makes periodic inspections of piers, wharves and other similar facilities in an effort to identify possible damage. The objectives are to avoid loss of lives and property that might occur should damage go undetected and to minimize the potential for reduced operational readiness.

The Navy initiated an underwater inspection program in 1980 to identify the nature and extent of damage to Navy waterfront structures. Condition assessments of such facilities have been conducted at approximately 50 Navy bases worldwide between 1980 and 1984. The Naval Facilities Engineering Command has tasked the Naval Civil Engineering Laboratory to develop a procedure for determining the optimum inspection frequency of waterfront structures.

Determining the optimum inspection frequency requires information on the current age of the structure, the material from which the support piles are made, the environment in which itis located, the condition of the facility, and mission requirements. While each of these factors vary from structure to structure, the use of proper techniques and procedures can help determine general trends in the data so that inspection frequencies can be established at intervals that minimize costs and maximize safety and readiness objectives.

The approach presented here involves the use of several statistical techniques, specifically multiple linear regression and logistic regression. Deterioration rates are calculated for timber, steel and concrete piles from measurement and descriptive information available in a computerized inspection data base.

Optimum inspection frequencies are obtained based on these existing data. The inspection frequencies integrate failure probabilities for piles and expected costs for pile repair or replacement. Total annual costs are generated for inspection intervals of 1 to 25 years.

BACKGROUND

This project is the culmination of an effort sponsored by the Naval Facilities Engineering Command (NAVFAC) to identify and evaluate procedures for determining optimum inspection frequencies for timber, steel and concrete waterfront structures. Prior to this time, no specific criteria were available for establishing the interval between inspections at waterfront facilities. While inspections were not carried out at haphazard intervals, they were subjected to funding constraints and subjective opinions of contractors conducting the inspections. A more suitable approach for determining the frequency of inspections was sought.

Earlier reports dealt with inspection strategies and maintenance costs associated with timber (Ref 1) and steel waterfront structures (Ref 2 and 3). Results for timber facilities indicated that the X-ray attenuation inspection method was the most economical procedure for pile maintenance. An annual benefit of $72.50 per pile was estimated based upon an inspection frequency of 14 years. An annual benefit of $97.00 per pile was estimated for facilities supported by steel piles with a corresponding inspection frequency of 10 years.

Deterioration models that form the basis of the techniques employed here have been previously described (Ref 4). Multiple linear regression techniques were suggested for use in obtaining timber and steel deterioration rates. Logistic regression was identified as a suitable procedure for estimating the number of concrete piles that fall within specific condition categories. The models represent an improvement over a probabilistic approach that had been proposed earlier (Ref 5). In addition, this report introduced the concept of sampling of piles as a procedure for characterizing the structural condition of a waterfront facility (Ref 5). Other sampling procedures were later identified in order to obtain cost-effective and representative data that would ultimately be used in the generation of the deterioration rates for timber, steel and concrete pile supported facility (Ref 6 and 7).

A Delphi survey was conducted to determine if data and criteria on inspection frequencies were available at commercial ports (Ref 8). The agencies contacted did not carry out any systematic inspections based on engineering assessments or cost/benefit analyses.

A computer data base was developed (Ref 9) to store and retrieve inspection and descriptive data obtained from Underwater Facilities Inspection reports generated by the Ocean Engineering and Construction Project Office. The data base is divided into six files that include specific information about each facility, including individual pile measurements, types of structural damage, maintenance and repair history, facility location, and environmental condition. At this time, the data base contains data on 526 timber, steel, and concrete waterfront structures.

Additional information is entered into the data base files as it becomes available.

In 1985, an interim report was prepared that presented inspection frequency criteria and identified many problem areas that are addressed herein (Ref 10). Some of the problem areas include the incorporation of structural and economic analysis into the inspection frequency model, establishing precedence of structural mission requirements, refining environmental subregions, determining the life expectancy of repairs, and verifying deterioration rates with additional inspection data. These problem areas are discussed in greater detail in this report.

ANALYTICAL PROCEDURES

Obtaining an optimum inspection frequency for a facility involves the integration of several factors, among which are pile deterioration rates, failure probabilities and associated costs for repair and/or replacement of the support elements. Calculation of deterioration rates is a necessary first step in determining the optimal inspection frequency. Deterioration rates are obtained by employing linear regression and logistic regression techniques. The deterioration models for timber, steel and concrete are described in this section. Common statistical terms used in this and subsequent sections are defined in Appendix A.

Timber Pile Analysis Model

Waterfront structures supported by timber piles deteriorate over time primarily as a result of attack by marine boring crustaceans and mollusks. Although timber piles are usually coated with a heavy layer of coal-tar creosote solution, the protection is not permanent and the piles become subject to biologically caused deterioration in a period of 5 to 10 years. The useful life of a timber pile has been reported to be about 20 years (Ref 10).

A method for determining the rate of deterioration of a timber pile over time is to measure the rate at which the pile diameter or effective area decreases. This can be accomplished by testing a number of pile elements under specific environmental conditions such as water temperature or current velocity and measuring the reduction in pile diameters at regular intervals. The difficulty with this approach is that substantial amounts of time and effort are needed to obtain the necessary data. A second method is to develop statistical models that rely on existing information about the condition of waterfront facilities. The inspection data base was developed to store and retrieve information from inspections and assessments of waterfront facilities. The procedure used for this analysis was a multiple linear regression technique (Ref 14). Multiple linear regression is a statistical method that can measure the contributions of a number of factors on the deterioration of a timber pile. The end result is a predictive model that estimates the decrease in pile diameter and the change in the pile coefficient of variation over time. The proposed regression model is:

delta DIA = A1 + A2*q(age) + A3*r(environmental condition) (1)

delta CV = B1 + B2*s(age) + B3*t(environmental condition) (2)

where delta DIA is the change in the diameter of the pile,

delta CV is the change in the coefficient of variation of the area of the pile,

q(age) and s(age) are functional transformations of the facility age,

r(environmental condition) and t(environmental condition) are functional transformations of the environmental condition of the facility,and

A1, A2, A3, B1, B2, and B2 are regression coefficients.

Regression coefficients are values that characterize the shape and form of the deterioration equations delta DIA and delta CV. As an example, if age were the only independent variable in the equations, the size and sign (either positive or negative) of the coefficient would indicate how quickly delta DIA or delta CV would change with respect to age of the piles.

Steel Pile Analysis Model

The primary cause of deterioration of steel piles is corrosion. The rate at which a steel pile corrodes is dependent upon several interrelated factors, *among which are environmental* conditions, the alloys from which the piles are manufactured, and the exposed zone of the pile (Ref 10). In this section, a model is proposed that estimates the rate of deterioration for steel piles.

The reduction in the area of the steel H-pile over time can be determined through the use of multiple linear regression analysis. The proposed model is similar to that for timber and is of the form:

$$\text{delta AREA} = C1 + C2*f(\text{age}) + C3*g(\text{environmental condition}) \quad (3)$$

$$\text{delta CV} = D1 + D2*h(\text{age}) + D3*j(\text{environmental condition}) \quad (4)$$

where delta AREA is the change in the area of the pile.

delta CV is the change in the coefficient of variation of the area of the pile,

f(age) and h(age) are functional transformations of the

facility age,

g(environmental condition) and j(environmental condition) are functional transformations of the environmental condition of the facility,and

C1, C2, C3, D1, D2, and D3 are regression coefficients.

The regression coefficients for steel can be interpreted in an identical manner to that of timber. A more detailed discussion of the regression approach can be found elsewhere (Ref 14).

Concrete Pile Analysis Model

The model proposed for the analysis of concrete piles has been developed in an earlier report (Ref 5) and is repeated here. The model is based on linear logistic techniques and is given in Equation 8. The model is:

$$E(Y) = \frac{e^{B0 + B1*X1 + B2*X2 + \ldots + Bn*Xn}}{1 + e^{B0 + B1*X1 + B2*X2 + \ldots + Bn*Xn}} \qquad (5)$$

where Y denotes the binary dependent (or response) variable and X1, X2,...,Xn are the independent variables. For concrete, Y equals 1 when membership in a particular concrete condition is affirmed or Y equals 0 when membership status is denied. As an example of this concept, Y equals 1 when the concrete condition code indicates that a pile is good (CCD = 0). Y equals 0 when the concrete conditon is any other value (i.e., CCD = 1,2,3,4, or 5). The independent variables (X1, X2, X3, etc.) may represent the age of the facility, the average temperature of the water surrounding a facility, the velocity of the water current, and the like. The independent variables may be binary, interval, or continuous measurements.

One major advantage of any logistic function is that it can be expressed in a linear form by taking the natural logarithm of both sides of the logistic equation. Equation 5 modified in this manner becomes

$$\ln[E(Y)/1-E(Y)] = B0 + B1*X1 + B2*X2 + \ldots + Bn*Xn \qquad (6)$$

The natural logarithm of the mean response is the probability that a pile will belong to the specified condition code for given values of the independent variables.

A hierarchical scheme using the logistic regression approach was attempted and is described here. The object of the scheme is to divide the six concrete condition codes into binary dependent variables using successively smaller groupings until each code is uniquely defined as a probability. For the first linear regression equation, the dependent variable Y equals 1 when the concrete condition code for a given pile is 0. Conversely, Y is equal to 0 when codes 1,2,3,4 or 5 apply. The resulting logistic equation will be of the form given in Equation 6 and will provide a probability that a pile will belong to concrete condition code 0. The hierarchical scheme is shown below.

1st level solution	$P(0)$ and $P(1,2,3,4,5)$
2nd level solution	$P(1) = P(1,2,3,4,5) * (1/1,2,3,4,5)$ $P(2,3,4,5) = P(1,2,3,4,5) * P(2,3,4,5/1,2,3,4,5)$
3rd level solution	$P(2) = P(2,3,4,5) * P(2/2,3,4,5)$ $P(3,4,5) = P(2,3,4,5) * P(3,4,5/2,3,4,5)$
4th level solution	$P(3) = P(3,4,5) * P(3/3,4,5)$ $P(4,5) = P(3,4,5) * P(4,5/3,4,5)$
5th level solution	$P(4) = P(4,5) * P(4/4,5)$ $P(5) = P(4,5) * P(5/4,5)$

For the second linear logistic equation, the binary response variable either equals 1 (for concrete condition code 1) or 0 (for codes 2, 3, 4, and 5). Again, the logistic equation will be of the form of Equation 6; however, the coefficients preceding the independent variables will be different from that of the previous equation and the result will be the condition probability that a pile will belong to condition code 1. The unconditional probability that a pile will be in concrete condition code 1 is the product of the probabilities that a pile belongs in condition codes 1, 2, 3, 4, or 5 and the conditional probability that it belongs in code 1.

Similar unconditional probabilities are formed for concrete condition code 2, 3, 4, and 5. Another method of obtaining the unconditional probability that a pile belongs to condition code 5 is to subtract from 1.0 the sum of the five previous unconditional probabilities P(0), P(1), P(2), P(3), and P(4).

It should be pointed out that the hierarchical scheme can be modified if necessary in order to take advantage of peculiarities in the data. The mathematical treatment of the hierarchical logistic regression scheme is discussed by Agresti (Ref 12).

TIMBER STRUCTURES

Timber pile data are available from 177 waterfront facilities in the inspection data base. However, much of the data is unsuitable for analyses as minimal data requirements were not met. Minimal requirements for the use of timber pile data are:

1. Timber piles are measured at the minimum diameter,

2. The diameter measurements were obtained through the use of calipers or an ultrasonic devise,

3. Piles were of the bearing or perimeter types,

4. Measurements of the original pile diameters (not the design diameters) were available in addition to measurement data from an inspection.

5. The data were collected in a random and/or unbiased manner.

Table 1. Descriptive Data for Timber Piles

Property Record Number	Location	Year Built	Year Inspected	Number of Pile Measurements	Percentage of Total
200051	Philadelphia	1940	1983	85	5.3
200052	Philadelphia	1940	1983	24	1.5
200053	Philadelphia	1940	1983	42	2.6
200054	Philadelphia	1940	1983	120	7.4
200055	Philadelphia	1940	1983	78	4.8
200056	Philadelphia	1940	1983	30	1.9
200057	Philadelphia	1900	1983	7	0.4
200064	Philadelphia	1903	1983	12	0.7
200069	Philadelphia	1919	1983	96	5.9
200071	Philadelphia	1940	1983	68	4.2
200072	Philadelphia	1944	1983	19	1.2
200073	Philadelphia	1940	1983	213	13.2
200155	Philadelphia	1919	1983	63	3.9
201299	Norfolk	1954	1984	117	7.2
201300	Norfolk	1954	1984	147	9.1
201301	Norfolk	1954	1984	183	11.3
201302	Norfolk	1954	1984	205	12.7
230500	Bangor	1978	1980	34	2.1
900087	Philadelphia	1941	1983	41	2.5
900088	Philadelphia	1941	1983	30	1.9

The data used in this analysis were obtained from the facilities listed in Table 1. The oldest facility was built in 1900 (Philadelphia) and the newest in 1978 (Bangor). The number of pile elements available for analysis totals 1614, with the least (7) and the most (213) located at facilities in Philadelphia. All the Philadelphia facilities were inspected in 1983, the Bangor facility in 1980, and the Norfolk facilities in 1984.

Timber Pile Analysis Results

Only five of 177 facilities had measurements of the original timber pile diameters for which a sample mean value and a standard deviation could be obtained (Property Record Number 201299, 201300, 201301, 201302 and 230500). The original pile measurements are important because, when used in conjunction of the final pile diameter measurements, the rate of the average pile deterioration over time can be calculated.

Instead of relying on original pile measurements, the design diameter for a facility was considered as an alternative. The design diameter is available for most timber waterfront structures and can be related to estimates of the original pile diameters. This association is apparent in Figure 1, where actual average diameter measurements are plotted against the assumed design diamters. The design diameters represent the minimum measurement for which a timber pile will be selected for use in the construction of a facility. The expected original mean pile diameter is related to the design diameter as shown in equation 7.

$$\text{ORIGINAL DIAMETER} = 3.1939 + (\text{DESIGN DIAMETER} * 0.8838) \qquad (7)$$

A facility with a design diameter of 12 inches, for example, has an expected original mean diameter of 13.80 inches.

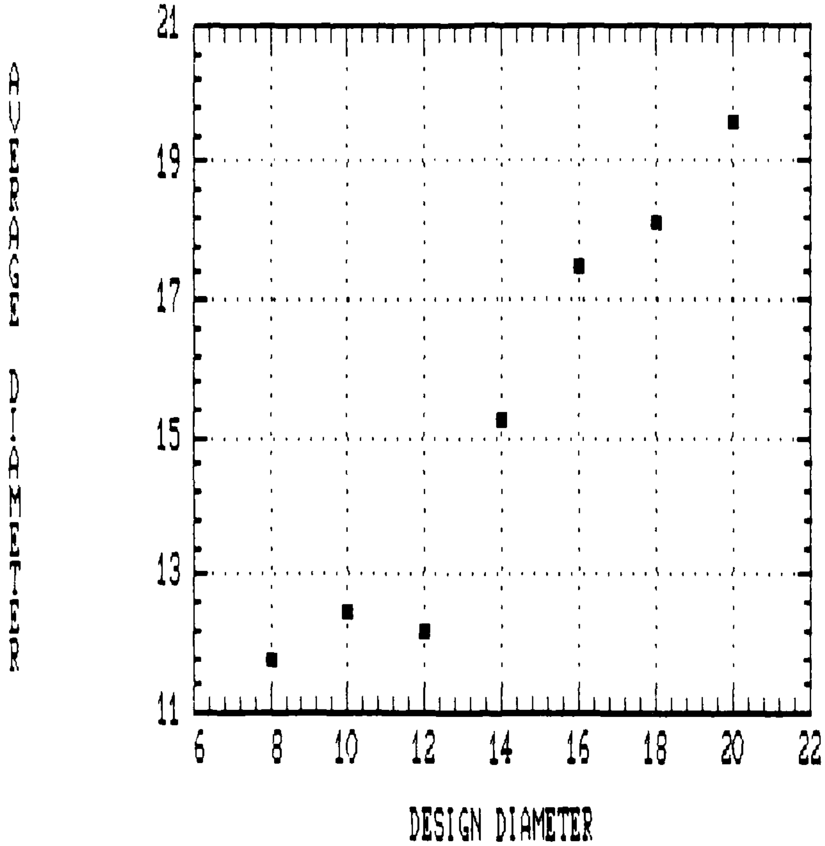

Figure 1. Plot of Average Diameter vs. Design Diameter

The rate of deterioration of timber pile diameters over time was calculated by using the the linear regression model described in the Analytical Procedures section. Timber piles were found to deteriorate at 0.0116 inches per year. Figure 2 shows the calculated rate of deterioration for facilities with design diameters of 8, 10, 12, 14 and 16 inches. This rate is considered to be extremely low and is based on the five timber facilities for which data are complete. This value is not a blanket rate that should be applied to all timber facilities. The bulk of the data from which this rate is obtained derive from four facilities located at Norfolk, Virginia. These facilities lie in formerly polluted brackish water. The quality of the water had undoubtedly prevented or considerably reduced the amount of attack by wood boring organisms.

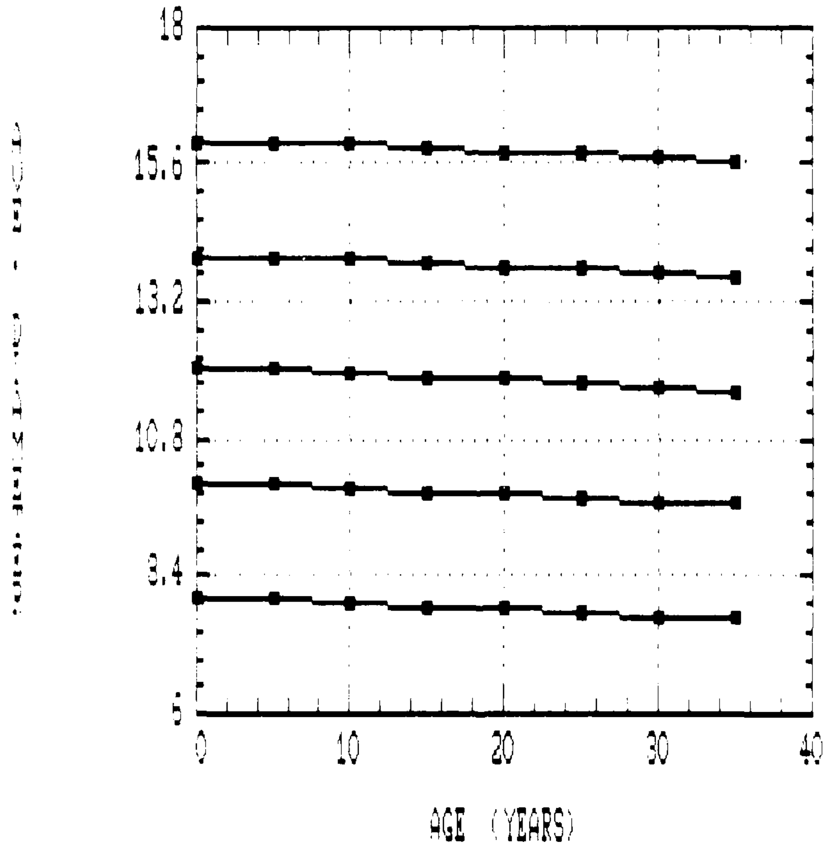

Figure 2. Reduction in Timber Pile Diameters

In a similar manner, the change in the coefficient of variation for timber piles had to be determined. The first step was to plot the original standard deviations and the mean diameter values to see if a correlation existed. If there were no correlation or if it were small, then it could be assumed that the original standard deviations were equal. This made estimating the coefficient of variation for the original timber piles much simpler. Figure 3 is a plot of the standard deviation and the mean diameter.

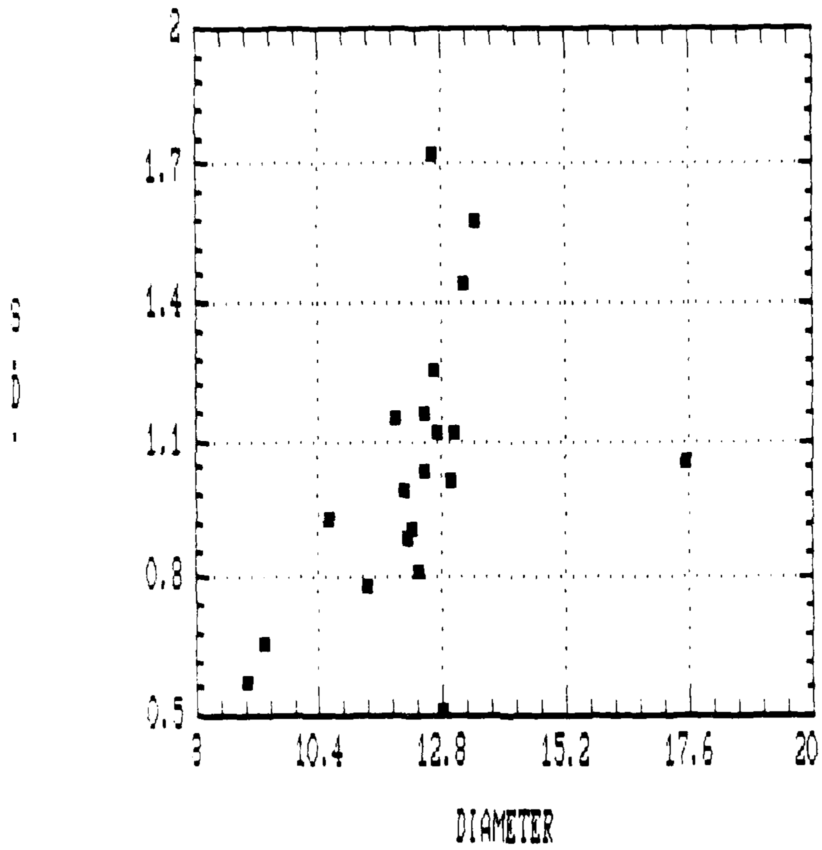

Figure 3. Plot of Standard Deviation vs. Mean Diameter

The calculated change in the coefficient of variation over time is shown in Figure 4. The rate of change increases 0.00086 per year. Like the rate of change for the decrease in the diameter of a timber pile, this rate is considered low. More timber pile data are required before accurate deterioration rates can be estimated.

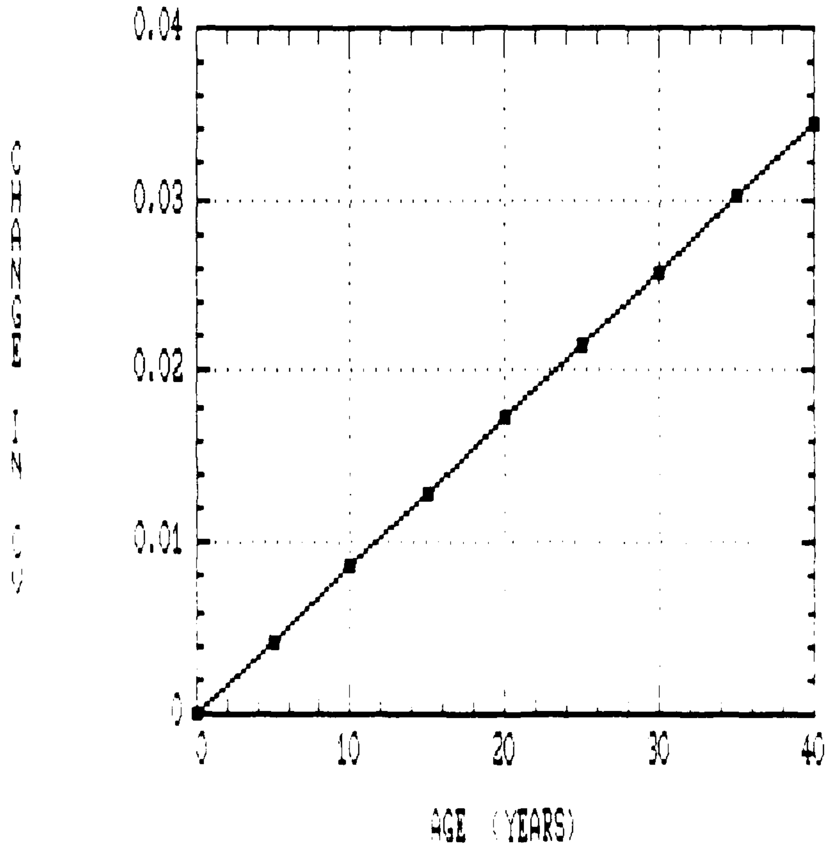

Figure 4. Increase in Timber Pile Coefficient of Variation

STEEL STRUCTURES

Waterfront structures supported wholly or in part by steel piles account for 144 of the 526 total facilities that are currently listed in the inspection data base. A review of most of the steel information contained in the data base revealed that data from only nine facilities were suitable for analyses. The nine facilities met the following minimal selection criteria.

1. Measurement data were restricted to thickness of flange (TW) or thickness of web (TF),

2. Measurement data were obtained from perimeter or bearing pile elements only, and

3. The data were collected in a random and/or unbiased manner.

The facilities used in the analyses of steel pile elements are presented in Table 3. Seven of the facilities are found on the east coast (New London, Charleston, and Manchester) and two represent west coast locations (San Clemente Island). The largest contingent of pile measurements was taken from the facility at Manchester. Less than 10% of the pile measurements were taken from each of the remaining facilities. The oldest facility was built in 1916 (Charleston). The newest facility was constructed in 1968 (New London). All facilities were inspected between 1975 and 1984.

Table 2. Descriptive Data for Steel Piles

Property Record Number	Location	Year Built	Year Inspected	Number of Pile Measurements	Percentage of Total
200307	New London	1968	1980	24	1.9
200344	New London	1947	1980	56	4.6
210418	Charleston	1916	1981	68	5.4
210419	Charleston	1943	1981	112	8.9
210829	Charleston	1942	1981	76	6.0
225724	San Clemente	1954	1984	81	6.4
225730	San Clemente	1954	1984	18	1.4
230151	Manchester	1941	1975 and 1980	767	61.0
900002	Newport	1957	1981	55	4.4

Unlike timber piles, where the most important measurement is the minimum diameter, steel H-piles require the measurements of several thicknesses before a rate of deterioration of the pile area can be determined. A steel H-pile is depicted in Figure 5. The area of a steel H-pile calculated is as follows:

$$\overline{A} = 2(BOF*\overline{TF}) + (DBF*\overline{TW}) \tag{8}$$

where BOF is the breadth of the flange,
TF is the flange thickness,
DBF is the distance between flanges,
and TW is the web thickness.

Note: DBF can be computed as DOB - 2*TF, where DOB is the depth of the beam.

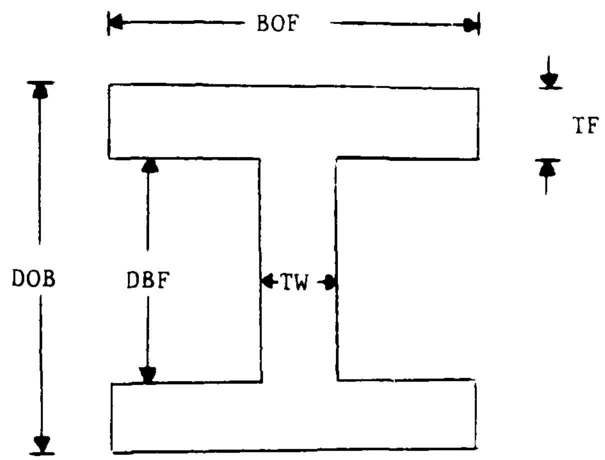

Figure 5. Steel Pile Dimensions

If the BOF measurement is assumed constant over time, then only TF and TW measurements are required to determine the mean and standard deviation of the H-pile areas. Equations 9 and 10 show the calculations for the mean area $\overline{A}$ and standard deviation S(A):

$$\overline{A} = 2*BOF*\overline{TF} + DBF*\overline{TW} \tag{9}$$

$$S(A) = [(2*BOF)^2 * S^2(TF) + DBF^2 * S^2(TW)]^{\frac{1}{2}} \tag{10}$$

where $\overline{A}$ is the average area,

$\overline{TF}$ is the average flange thickness,

$\overline{TW}$ is the average web thickness,

S(A) is the standard deviation of the area,

S(TF) is the standard deviation of the flange thickness, and

S(TW) is the standard deviation of the web thickness

Steel Pile Analysis Results

Results from the several computer runs are summarized in Figures 6, 7, and 8 and in Tables 3 and 4. Figures 6 and 7 depict the rate of pile area deterioration over time for the four types of steel H-piles used in the support of the selected facilities. The design measurements of the H-piles are presented in Table 3. Flange thicknesses were found to decrease at a rate of 0.00351 in/yr and web thickness at a rate of 0.00313 in/yr. Figure 8 shows the overall increase in the standard deviation of the pile area as time increases. The standard deviation for both flange and web thicknesses increased at a rate of 0.0024 in/yr. These figures are based on results generated from computer runs using the BMDP 9R statistical software (Ref 11). Attempts made to divide the deterioration rates into environmentally distinct regions proved unsuccessful as not enough data were available.

Table 3. Design Measurements for Steel H-Piles

Measurement Type	Pile Type HP14x89	HP14x73	HP12x74	HP12x53
TF	0.615	0.505	0.605	0.435
TW	0.615	0.505	0.610	0.435
BOF	14.695	14.585	12.215	12.045
DOB	13.830	13.610	12.130	11.780

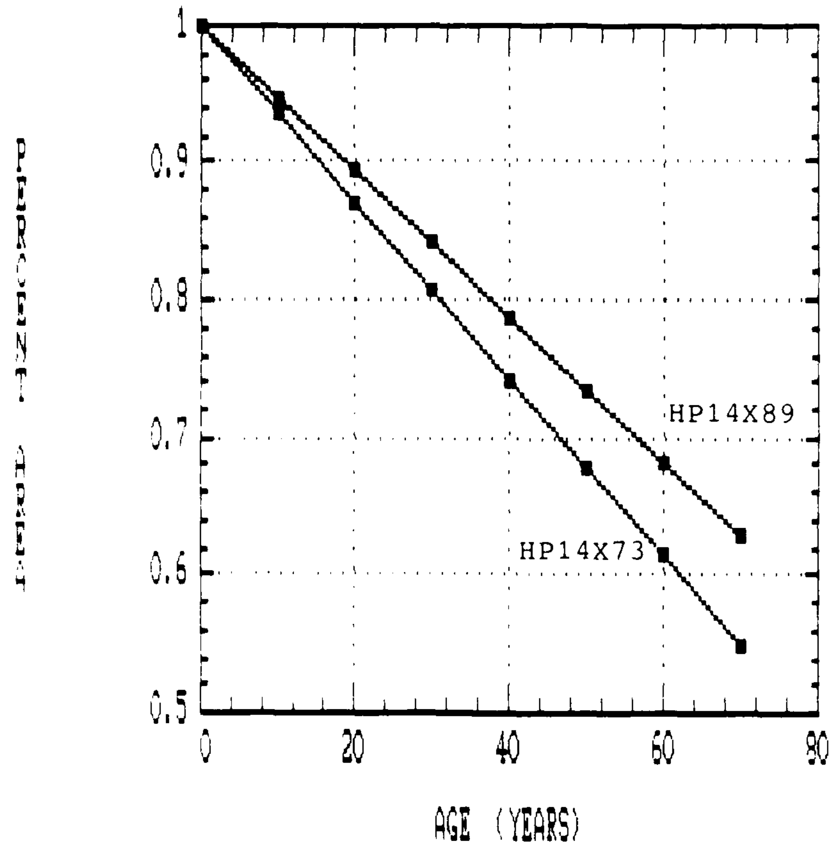

Figure 6. Percent Area Remaining for HP14x89 and HP14x73

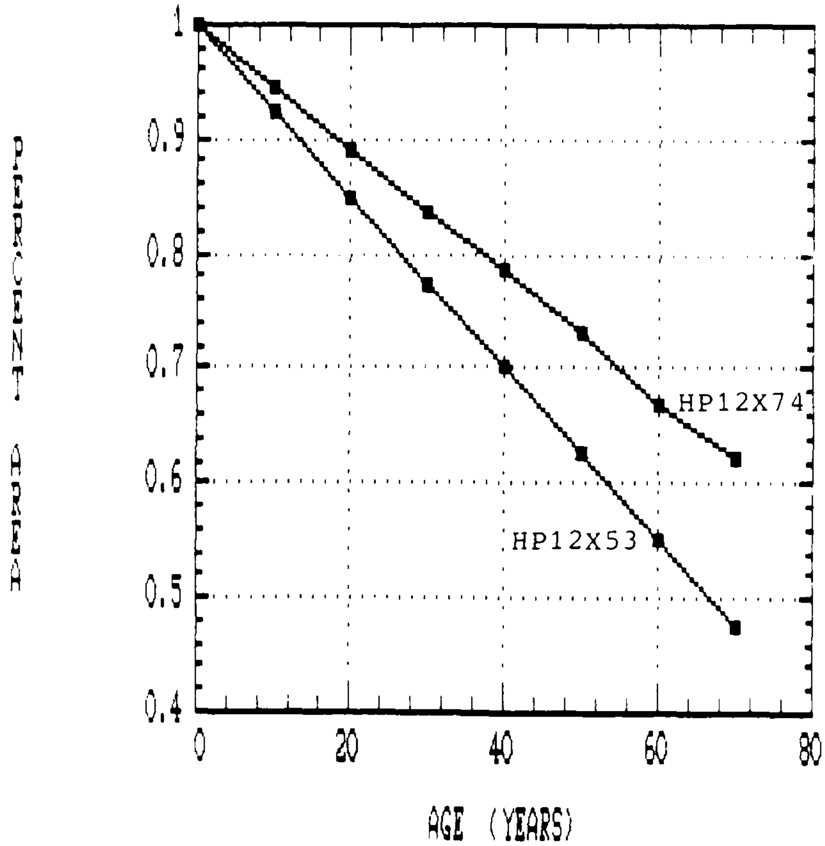

Figure 7. Percent Area Remaining for HP12x74 and HP12x53

Table 4. TF and TW Measurements

Property Record Number	TF Mean Thickness Loss	TF Standard Deviation	TW Mean Thickness Loss	TW Standard Deviation
200307	0.06808	0.00567	0.10933	0.02049
200344	0.07800	0.05424	0.10975	0.12921
210418	0.08165	0.04270	0.09243	0.04949
210419	0.13733	0.07392	0.12364	0.06568
210829	0.12589	0.05443	0.14497	0.06170
225724	0.12115	0.22100	0.01167	0.00651
225730	0.03955	0.03020	0.11000	0.02345
230151	0.13808	0.08157	0.10025	0.03251
900002	0.18479	0.12668	0.13915	0.09798

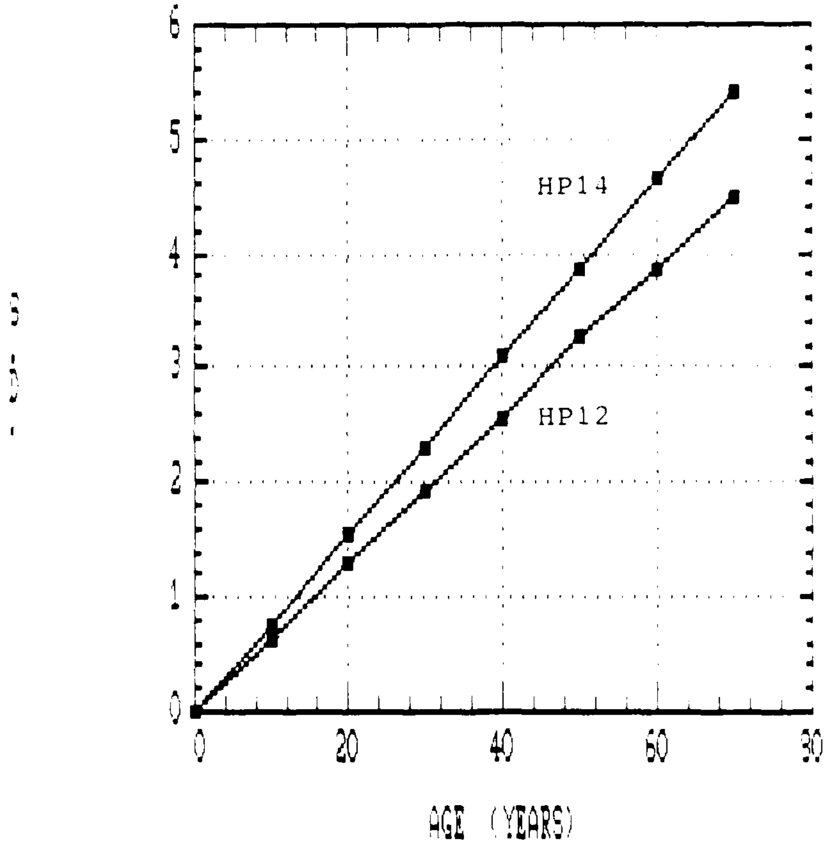

Figure 8. Rate of Change of Standard Deviation for Pile Area Measured in Square Inches

CONCRETE STRUCTURES

Waterfront structures built with concrete piles are located in several locations throughout the continental United States and at Naval activities throughout the world. To date, 315 facilities listed in the data base are supported entirely or partially by concrete piles. Of these 315 facilities, only 12 had met minimally sufficient requirements to warrent further data analysis. These requirements were:

1. That concrete pile deterioration be measured by the general condition code indicated in the data base management report (Ref 9) and shown here as:

Concrete Condition Code	Description
0	good condition, no apparent problems
1	hairline cracks (<1/8 inch wide)
2	failure cracks (>1/8 inch wide)
3	spalled concrete on surface (< 1 inch deep)
4	deeply spalled concrete (> 1 inch deep)
5	failed pile (no apparent bearing capacity)

2. Data on piles were restricted to bearing or perimeter elements, and

3. The data were collected in a random and/or unbiased manner.

The facilities that met these requirements are listed in Table 5. Seven of the facilities are found along the southeastern portion of the United States coastline (Jacksonville, Charleston, and Yorktown). Two west coast locations (San Diego and Bangor) were represented in the sample. The number of piles of a facility available for analysis ranged from 19 (Charleston) to 1374 (Bangor) The oldest facility was constructed in 1908 (San Diego) and the newest was built in 1979 (Bangor). One half of the facilities in the sample were completed in the 1940's. Over half of the piles are represented by the facilities in Bangor, Washington. Inspection of all facilities took place from 1980 to 1984.

Table 5. Descriptive Data for Concrete Piles

Property Record Number	Location	Year Built	Year Inspected	Number of Piles	Percentage of Total
200133	Jacksonville	1953	1983	218	5.5
200149	Charleston	1947	1981	88	2.2
200173	Charleston	1947	1981	90	2.3
200445	San Diego	1908	1980	48	1.2
200499	Yorktown	1942	1980	208	5.3
200450	San Diego	1941	1983	597	15.1
200593	Charleston	1977	1981	19	0.5
201368	San Diego	1930	1980	40	1.0
210119	Charleston	1947	1984	228	5.8
221444	Jacksonville	1978	1983	54	1.4
230242	Bangor	1945	1981	983	24.9
230700	Bangor	1979	1981	1374	34.8

Table 6. Raw Counts for Concrete Piles

Property Record Number	Concrete Condition Code						
	0	1	2	3	4	5	Total
200133	198	6	5	3	6	0	218
200149	87	0	0	0	0	1	88
200173	89	0	0	0	0	1	90
200445	48	0	0	0	0	0	48
200450	574	1	8	8	6	0	597
200499	160	7	4	34	3	0	208
200593	19	0	0	0	0	0	19
201368	40	0	0	0	0	0	40
210119	177	24	9	15	3	0	228
221444	51	2	0	0	0	1	54
230242	941	2	21	8	8	3	983
230700	1362	12	0	0	0	0	1374
Total	3746	54	47	68	26	6	3947

Table 6 presents the number of piles in each concrete condition code category for each property record. Inspection of the table suggests that some of the data may not be completely suitable for the logistic regression analysis. For example, although facility 200445 is the oldest structure in the sample, none of its piles show any indication of damage. Several runs of the BMDP logistic regression program (Ref 11) were made in an effort to determine the most statistically significant model. Results of the logistic regression approach are presented in the next section.

Concrete Pile Analysis Results

Early computer runs of the logistic regression model incorporating all the sample data provided statistically insignificant results. Because of this, data from facilities 200149, 200173, 200445, and 201368 were removed as they represented incomplete or spurious information. For example, although facility 200445 was built in 1908, there were no data to suggest that any deterioration of the piles occurred or that any previously damaged piles had been repaired or replaced. This seems highly unlikely in light of the information presented in Table 6 for the other facilities that were much younger.

Once initial data screening was complete, further computer runs were made on all the remaing data. In addition, other runs were made after the collective data were divided into east and west coast groups. For each grouping (all data, east coast data, west coast data), significant results were obtained for heirarchical level 1 only. Levels 2 through 5 provided no statistically significant results. The principal reason for this is that there were not enough data in the remaining condition code categories to implement the logistic regression procedure any further. For example, only 6 of the 3947 concrete piles fall within condition code 5. Output of the BMDP computer runs for each grouping are presented in Volume II of this report. Deterioration models incorporating the age of the facility are presented in Table 7.

Table 7. Logistic Regression Results

Grouping	Logistic Regression Equation
All	$\ln[Y1/(1-Y1)] = 4.3908 - 0.0519*AGE$
East Coast	$\ln[Y1/(1-Y1)] = 4.7740 - 0.0411*AGE$
West Coast	$\ln[Y1/(1-Y1)] = 4.4626 - 0.0843*AGE$

Damage probabilities for concrete piles based on these logistic regression equations are depicted in Figure 9. A total of 3681 piles were used in the analysis of all the data. East and west coast results were based on 728 and 2954 piles, respectively. Damage probabilities on which Figure 9 is based are given in Table 8. The analysis of the data indicates a sizable difference between the deterioration rates on the east and west coasts. The probability of damage for concrete piles on the east coast are considerably less than for piles located on the west coast as the age of the facility increases. At an age of 20 years, for example, 5% of piles situated on the eastern seaboard are expected to exhibit some signs of deterioration (i.e. the damaged piles will be classified as condition code categories 1,2,3,4 or 5). For facilities located on the west coast, however, over 14% of the piles will have deteriorated to some degree.

Table 8. Damage Probabilities for Concrete

AGE	ALL FACILITIES	EAST COAST FACILITIES	WEST COAST FACILITIES
5	0.0418	0.0282	0.0456
10	0.0536	0.0244	0.0679
15	0.0683	0.0420	0.0999
20	0.0868	0.0511	0.1447
25	0.1097	0.0620	0.2050
30	0.1378	0.0751	0.2822
35	0.1716	0.0907	0.3747
40	0.2117	0.1091	0.4774
45	0.2582	0.1307	0.5820
50	0.3109	0.1559	0.6797

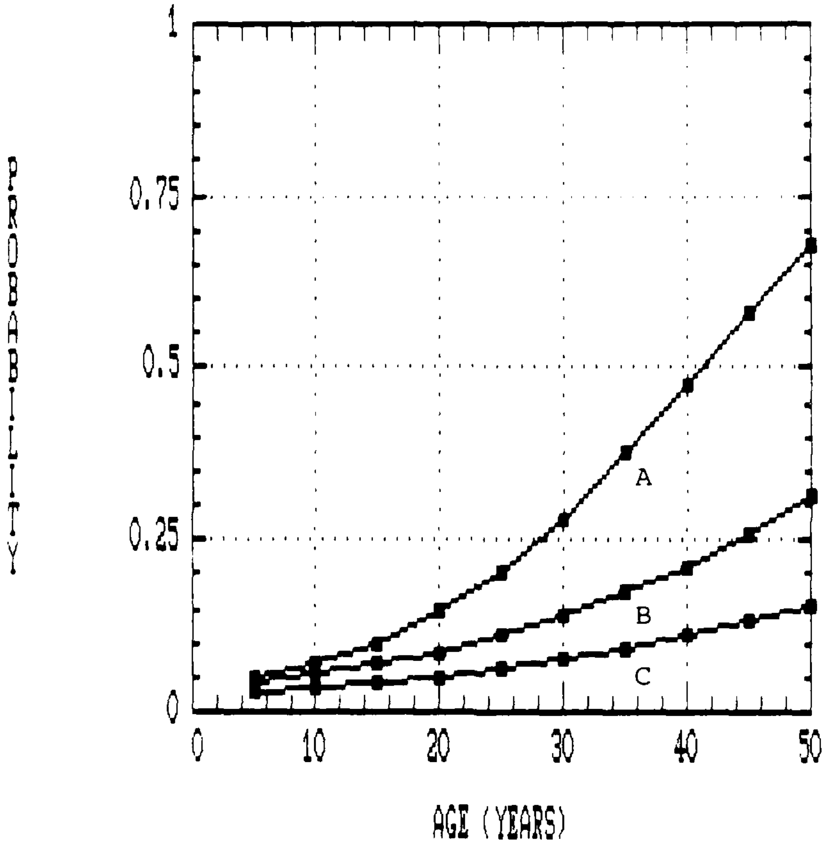

Figure 9. Graph of Probability of Damage

Curve A: West Coast Facilities
Curve B: West and East Coast Facilities
Curve C: East Coast Facilities

STRUCTURAL ANAYSIS

A structural analysis technique for estimating the probability of failure of timber and steel piles was previously developed (Ref 15) and is decribed below. In this technique, the safety index (β) is calculated as shown in equation 11.

$$\beta = \frac{\ln \bar{\Theta}}{\delta_T} \tag{11}$$

where $\bar{\Theta}$ = $\bar{R}/\bar{L}$ = mean factor of safety

$\bar{R}$ = mean structural resistance

$\bar{L}$ = mean value of the applied load

δ_T = $\sqrt{\delta_r^2 + \delta_l^2}$ = total coefficient of variation

δ_r = $\sqrt{\delta_f^2 + \delta_g^2}$ = coefficient of variation of structural resistence

δ_l = coefficient of variation of applied load

δ_f = coefficient of variation of material strength

δ_g = coefficient of variation of geometry

The safety index is related to the probability of failure of an individual pile. The relationship is shown in equation 12.

$$P_f = 1 - \Phi(\beta) \tag{12}$$

where P_f = the probability of failure of an individual pile, and

$\Phi(\beta)$ = the probability density function of the standard normal distribution

Estimates for the variables found in equation 10 have been previously documented (Ref 15). The coefficient of variation of geometry is calculated for each facility depending on the standard

deviations and means for the timber pile diameters and steel areas. These values are obtained from the measurement data in the underwater inspection data base. An example showing the timber pile calculations is provided elsewhere (Ref 15).

The structural analysis of concrete does not lend itself well to the procedure used for timber and steel. The primary reason for this is that concrete does not degrade in a manner similar to the other construction materials. Damaged concrete piles exhibit cracks or spalling, not deterioration measured as a loss of cross-sectional area. However, the heirarchical logistic regression model provides a method for estimating the probability that an individual pile will fail or will be damaged. Multiplying the number of piles at a facility by the probability of failure or damage will give the estimated number of piles that fail within each condition code category.

INSPECTION FREQUENCIES

The inspection frequency model incorporates deterioration rates, failure probabilities, and repair various costs for timber, steel and concrete pile supported waterfront structures. Failure probabilities are determined by use of the structural analysis methods described in the previous section. Total annual costs that are incurred during inspection, maintenance, and repair of a facility are discussed here. Computer software was developed that integrates each element of the analysis and inspection frequency costs were generated for inspection periods 1 through 25 years. The inspection year that yields the lowest cost is considered the period at which an inspection should take place.

Inspection Costs

Inspection costs are calculated by determining the number of piles in a facility that are visually inspected or are inspected in a more intensive manner. For timber, the cost of inspection is computed by multiplying the the number of piles inspected by the inspection cost per pile. The current inspection costs per pile for timber are:

Level 1: $18.00

Level 2 or 3: $25.00

Steel pile inspection costs are determined in a similar manner. Level 2 or 3 inspection costs were initially estimated at $60.00 per pile using an ultrasonic device to make pile measurements. Other inspection costs might be more appropriate if other inspection methods are used. The inspection costs for H-piles are:

Level 1: $18.00

Level 2 or 3: $60.00

Concrete inspection costs are:

Level 1: $18.00

Level 2 or 3: $25.00

Incorporated into the cost of inspection are the number of piles that are subjected to a Level 1 or Level 2 or 3 inspection.

piles that are subjected to a Level 1 or Level 2 or 3 inspection. Sampling procedures for Level 2 or 3 inspections are discussed in Ref 17. Inspection costs are calculated in the following manner.

Cost of Inspection = [(no. of piles sampled) (cost of Level 2 or 3 inspection) + (no. of piles not sampled) (cost of Level 1 inspection)]/ (inspection period)

The costs for the various levels of inspection can be modified by the software user whenever necessary.

Repair Costs

Repair costs are for timber, steel and concrete piles greatly differ. Wrapping and jacketing timber piles are the principal choices for pile repair. The current costs per pile are (Ref 1):

Wrapping cost: $720.00

Jacketing cost: $3600.00

The costs for steel piles are (Ref 3):

H-pile repair: $2000.00

Repair costs for concrete piles vary depending on the nature of the damage. Filling cracks with epoxy grout is estimated to cost $1150.00 per crack while patching of spalled concrete is estimated at $16.50 per square foot (Ref 16). All repair costs can be change by the software user when required.

Repair costs for timber are calculated as follows.

Cost of Repair = [(no. of piles wrapped) (wrapping cost) + (no. of piles jacketed) (jacketing cost) + (no. of piles replaced) (replacement cost)]/ (inspection period).

Repair costs for steel and concrete structures are:

Cost of Repair = [(no. of piles repaired) (repair cost)]/ (inspection period).

Failure Costs

At a minimum, failure costs are calculated by multiplying the the product of the number of piles in a facility and the probability that a pile will fail by the cost to replace a pile. The costs to replace piles are:

Timber: $3600.00

Steel H-piles: $3500.00

Concrete: $3500.00 - $5000.00

Also included in computing the total failure cost are the costs associated with the loss of equipment, the loss of life, and the loss of use of a facility should catastrophic failure take place.

The cost of failure is given by:

Cost of Failure = [(no. of failed piles) (replacement cost)+ (cost of lost equipment) + (cost of loss of (life) + (cost of loss of use of facility)]

Inspection Frequency Computer Software and Results

The software used to generate the optimum inspection frequencies was designed to run on an IBM-XT microcomputer. The software runs on DOS 3.1 and requires at least 128K of RAM. While an 8087 or similar math co-processor is not required to run the software, the use of a co-processor will improve running time considerably. The software has an option to send results to a line printer. Any printer normally used with the IBM-XT will work with this software.

The computer software was developed to provide inspection frequency costs for inspection periods of 1 to 25 years. The lowest total costs calculated by summing the costs for inspection, repair, and failure provide an indication of the time that an inspection would be most appropriate. A flow diagram of the software is provided in Figure 10.

Examples of typical output for timber, steel, and concrete piles are shown on the following pages. For each inspection period, the cost of inspection, repair, and failure are provided. Total costs are given as well. The costs are based on the indicated input values.

TIMBER INPUT VALUES

MEAN COEFFICIENT:	.014400
STANDARD DEV. COEF:	.042100
LEVEL 1 INSPECTION COST:	18.00
LEVEL 2 OR 3 INSPECTION COST:	25.00
WRAPPING COST:	720.00
JACKETING COST:	3600.00
REPLACEMENT COST:	3600.00
EQUIPMENT LOSS COST:	.00
LOSS OF LIFE COST:	.00
LOSS OF USE COST:	.00
CONFIDENCE LEVEL:	.95
DESIRED ACCURACY:	.10
WRAPPING THRESHOLD:	.95
JACKETING THRESHOLD:	.85
REPLACEMENT THRESHOLD:	.50
AGE OF PIER:	10
NUMBER OF PILES IN PIER:	1000
DESIGN PILE DIAMETER (IN):	12.00
MEAN PILE DIAMETER (IN):	13.00
S.D. OF PILE DIAMETER (IN):	1.20
AGE AT WHICH DETERIORATION BEGINS:	5
FACTOR OF SAFETY:	2.00

EXPECTED ANNUAL COSTS

INSPECTION PERIOD	INSPECTION COST	REPAIR COST	FAILURE COST	TOTAL COST
1	18238.	1611360.	57600.	1687198.
2	9123.	815400.	57600.	882123.
3	6086.	550320.	61200.	617606.
4	4567.	416880.	64800.	486247.
5	3655.	336816.	68400.	408871.
6	3047.	283560.	72000.	358607.
7	2612.	245006.	72000.	319618.
8	2288.	216090.	75600.	293978.
9	2034.	193280.	79200.	274514.
10	1832.	175032.	82800.	259664.
11	1666.	160102.	86400.	248167.
12	1527.	147660.	93600.	242787.
13	1411.	136634.	97200.	235245.
14	1311.	127697.	100800.	229808.
15	1224.	119712.	104400.	225336.
16	1148.	112725.	108000.	221873.
17	1081.	106560.	115200.	222841.
18	1021.	100920.	118800.	220741.
19	968.	95874.	126000.	222842.
20	920.	91296.	129600.	221816.
21	876.	87189.	136800.	224865.
22	837.	83455.	140400.	224692.
23	801.	79889.	147600.	228290.
24	768.	76800.	151200.	228768.
25	738.	73786.	158400.	232923.

STEEL INPUT VALUES

MEAN COEFFICIENT:	.003370
ST. DEV. COEF:	.002400
LEVEL 1 INSPECTION COST:	18.00
LEVEL 2 OR 3 INSPECTION COST:	60.00
REPAIR COST:	2000.00
REPLACEMENT COST:	3500.00
EQUIPMENT LOSS COST:	.00
LOSS OF LIFE COST:	.00
LOSS OF USE COST:	.00
CONFIDENCE LEVEL:	.950
DESIRED ACCURACY:	.010
WRAPPING THRESHOLD:	.950
REPLACEMENT THRESHOLD:	.700
AGE OF PIER:	10
NUMBER OF PILES IN PIER:	1000
ORIGINAL MEAN PILE AREA (SQ. IN.):	15.500
FINAL MEAN THICKNESS (IN.):	.390
FINAL S.D. OF THICKNESS (IN.):	.060
BOF MEASUREMENT (IN.):	12.045
DOB MEASUREMENT (IN.):	11.780
AGE AT WHICH DETERIORATION BEGINS:	5
FACTOR OF SAFETY:	2.00

EXPECTED ANNUAL COSTS

INSPECTION PERIOD	INSPECTION COST	REPAIR COST	FAILURE COST	TOTAL COST
1	52314.	1537500.	10500.	1600314.
2	26304.	790750.	14000.	831054.
3	17634.	542667.	17500.	577801.
4	13289.	418000.	21000.	452289.
5	10681.	343400.	28000.	382081.
6	8936.	293917.	31500.	334353.
7	7695.	257929.	42000.	307624.
8	6760.	230938.	49000.	286697.
9	6032.	209667.	63000.	278699.
10	5446.	192650.	73500.	271596.
11	4966.	178545.	87500.	271011.
12	4570.	166333.	105000.	275903.
13	4228.	155846.	126000.	286074.
14	3938.	146607.	147000.	297545.
15	3686.	138367.	171500.	313553.
16	3464.	131063.	196000.	330526.
17	3270.	124500.	224000.	351770.
18	3095.	118389.	255500.	376984.
19	2939.	112447.	290500.	405886.
20	2798.	107300.	325500.	435598.
21	2671.	102381.	364000.	469052.
22	2554.	97682.	406000.	506235.
23	2448.	93326.	448000.	543774.
24	2350.	89188.	490000.	581537.
25	2261.	85320.	535500.	623081.

CONCRETE INPUT VALUE

INTERCEPT COEFFICIENT:	4.390800
MEAN COEFFICIENT:	-.051900
LEVEL 1 INSPECTION COST:	18.00
LEVEL 2 OR 3 INSPECTION COST:	25.00
REPAIR COST:	1150.00
REPLACEMENT COST:	5000.00
EQUIPMENT LOSS COST:	.00
LOSS OF LIFE COST:	.00
LOSS OF USE COST:	.00
CONFIDENCE LEVEL:	.90
DESIRED ACCURACY:	.05
EXPECTED ATTRIBUTE PROPORTION:	.10
AGE OF PIER:	5
NUMBER OF PILES IN PIER:	2000
AGE AT WHICH DETERIORATION BEGINS:	10

EXPECTED ANNUAL COSTS

INSPECTION PERIOD	INSPECTION COST	REPAIR COST	FAILURE COST	TOTAL COST
1	36651.	0.	0.	36651.
2	18326.	0.	0.	18326.
3	12217.	0.	0.	12217.
4	9163.	0.	0.	9163.
5	7330.	0.	0.	7330.
6	6109.	16867.	13200.	36175.
7	5236.	15114.	13800.	34150.
8	4581.	13944.	14550.	33075.
9	4072.	13033.	15300.	32406.
10	3665.	12305.	16050.	32020.
11	3332.	11814.	16950.	32096.
12	3054.	11308.	17700.	32063.
13	2819.	10969.	18600.	32389.
14	2618.	10679.	19500.	32797.
15	2443.	10503.	20550.	33497.
16	2291.	10278.	21450.	34019.
17	2156.	10215.	22650.	35021.
18	2036.	10094.	23700.	35831.
19	1929.	10047.	24900.	36876.
20	1833.	10005.	26100.	37938.
21	1745.	9967.	27300.	39012.
22	1666.	9984.	28650.	40300.
23	1594.	10000.	30000.	41594.
24	1527.	10063.	31500.	43090.
25	1466.	10074.	32850.	44390.

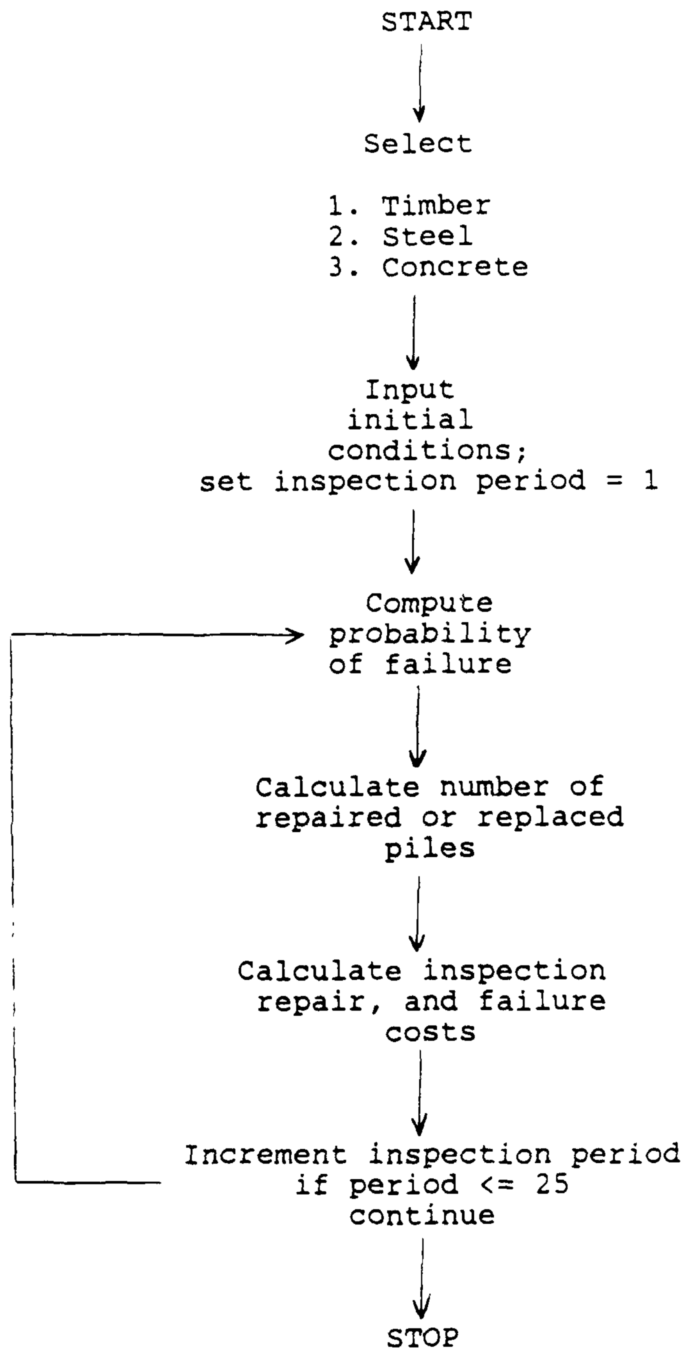

Figure 10. Flow Diagram of Inspection Frequency Computer Software

CONCLUSION

The purpose of this report was to test and document procedures for determining the optimum inspection frequency of timber, steel, and concrete pile supported waterfront structures. The principal consideration was to identify those inspection frequencies that were most cost-effective. Deterioration curves were developed for facilities that were constructed from each type of building material. Difficulties encountered during the data collection phase of the project were noted and modifications to procedures were implemented in order to achieve the best model fit for the data at hand.

The deterioration curves were based on statistical linear regression and logistic regression techniques. Linear regression was most suited for the timber and steel data while the hierachical logistic regression approach was better suited for concrete piles. Both techniques can take advantage of information that pertain to the age, the general surrounding environmental condition of the facility, and similar useful data in evaluating the degree to which these factors contribute to the overall deterioration of a pile. Sample output from the various regression runs are included in Volume II of this report.

As with any statistical approach, the estimates of the predictive model coefficients are only as good as the data from which the estimates are derived. The estimated coefficients will undoubtedly lead to improved deterioration curves as new information is added to the data base. That new data are needed is emphasized by the fact that only eight of the almost 300 facilities supported wholly or in part by concrete piles were found suitable for inclusion in the analysis of the concrete data. Likewise, there is an insufficient amount of good timber pile data. Steel pile data are, for the most part, adequate at this time.

Inspection frequencies were generated for the three timber, steel and concrete facility types. Computer software was developed that incorporated deterioration rates and cost estimates that were unique to each type of pile material. The user-friendly software was designed to provide inspection frequencies for a facility under any set of initial conditions. The inspection frequency costs provided in the previous section are for three distinct facilities. Different inspection frequency costs can be generated for other facilities where input values for the initial conditions vary.

An interim inspection frequency report (Ref 10) made a number of recommendations for an improved inspection plan. Seven suggestions were proposed; six of these are included below and require comment. The six suggestions are:

1. Incorporate detailed structural and economic analysis into the frequency criteria,

2. Establish precedence of facility mission requirements,

3. Refine environmental subregions,

4. Determine life expectency of repairs,

5. Investigate structures that have questionable maintenance history records and deterioration rates, and

6. Verify deterioration curves with additional inspection data.

To date, attempts have been made to act upon all recommendations. Structural and economic analyses have been incorporated into the inspection frequency model, structures with questionable maintenance histories have been investigated and changes, if any, have been reported, and deterioration rates for each type of pile material have been improved.

Recommendations 2, 3 and 4 have met with less success. Although no information exists in the inspection data base that give mission requirements for any of the waterfront facilities, precedence for facility mission requirements can be incorporated into the inspection frequency model by establishing acceptable limits for the probability that a single pile will fail. Because it is obvious that deterioration of piles that support a munitions pier would present a greater hazard than a facility that supports foot traffic, threshhold failure probabilities might be limited to smaller failure probabilities for facilities with more sensitive mission ratings.

Environmental subregions were not identified in any analysis except dividing the deterioration rates into east and west coast subareas for concrete piles. Further refinement was not possible given the lack of sufficient information present in the inspection data base. However, computer tapes containing environmental data has been recieved from NOAA.

Few data were available for determining the life expectancy of repaired piles. Jacketing and wrapping of timber piles, for example, adds additional years to the life of a pile. The rate at which a wrapped or jacketed timber pile deteriorates is not known, although some estimates have been provided (Ref 16). These estimates, however, could not be validated.

RECOMMENDATIONS

The following recommendations are proposed in an effort to improve the optimum inspection frequency procedure. The recommendations are:

1. Refine the rates of deterioration for the different pile types. Additional data are primarily needed for timber and concrete piles.

2. Obtain new deterioration rates for piles in different geographical areas as additional data become available.

3. Evaluate the optimum inspection frequency model with actual facility inspection data. Update the model as necessary.

The implementation of these recommendations will provide better estimates of the optimum inspection periods during selected runs of the software. Further, the inclusion of refined data will result in a realization of additional cost savings.

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APPENDIX A

GLOSSARY OF TERMS

The following is a brief list of terms used in the report.

1. POPULATION - A population is a set of items that have some common observable characteristic. The set of all timber piles that support Naval waterfront facilities would constitute a population.

2. SAMPLE - A sample is a smaller set of items selected from the population. The set of timber piles used to obtain the regression coefficients for calculating the deterioration rates are a sample.

3. PARAMETER - A parameter is a characteristic of a population. The average value of pile diameters in a population would be a characteristic of the population if measurements were taken from all the timber piles in order to calculate the parameter.

4. STATISTIC - A statistic is a characteristic of a sample. The statistic is calculated from the observations of some percentage of the population. This characteristic can be used to make a statement about the population. For example, the average value of the diameters obtained from the sample could be used as an estimate of the average diameter of the population of timber piles.

5. MEAN - The mean value is one of the most commonly used statistics. It indicates the average of most likely value of the characteristic of interest. The mean value is calculated by dividing the sum of all observations that form the sample by the total number of observations.

6. VARIANCE - The variance provides a description of dispersion of the data from some measurement of central tendancy. This statistic is calculated from the sum of the squared differences between the mean and each of the data observations.

7. STANDARD DEVIATION - This statistic is the square root of the varaince. The standard deviation is a more commonly used descriptor of dispersion than the variance as the units of this statistic are in the same units as the data observations.

8. COEFFICIENT OF VARIATION (COV) - The COV is a relative measure that relates the magnitude of a statistic to the mean value. It relates the standard deviation and the mean by expressing the standard deviation as a percentage of the mean.

APPENDIX B

INSPECTION FREQUENCY COMPUTER
SOFTWARE LISTING

The computer programs used in the determination of the inspection frequencies are presented in this appendix. The programs are:

1. PIER.BAT - a batch driver program used to initiate the start of each individual program

2. DRIVER.BAS - a Basic program that sets up the initial screen menu

3. PTIM.FOR - a Fortran 77 program that generates the inspection frequencies for timber facilities.

4. PST.FOR - a Fortran 77 program that generates the inspection frequencies for steel H-pile facilities.

5. S.FOR - a Fortran 77 program that generates the inspection frequencies for steel sheet pile facilities

6. PCON.FOR - a Fortran 77 program that generates the inspection frequencies for concrete facilities.

Two slightly different versions of PIER.BAT and DRIVER.BAS were created. The first versions were developed for timber and steel optimum inspection frequencies. The second versions were developed for concrete. Printouts for each versions of these programs are included.

PIER.BAT

FOR TIMBER AND STEEL

```
ECHO OFF
CLS
:ABC
BASIC DRIVER
IF EXIST 1.111 GOTO :1
IF EXIST 2.222 GOTO :2
IF EXIST 3.333 GOTO :3
IF EXIST 4.444 GOTO :4
:1
ERASE 1.111
PTIM.EXE
GOTO :ABC
:2
ERASE 2.222
PST.EXE
GOTO :ABC
:3
ERASE 3.333
S.EXE
GOTO :ABC
:4
ERASE 4.444
CLS
```

FOR CONCRETE

```
ECHO OFF
CLS
:ABC
BASIC DRIVER
IF EXIST 1.111 GOTO :1
IF EXIST 2.222 GOTO :2
:1
ERASE 1.111
PCON.EXE
GOTO :ABC
:2
ERASE 2.222
CLS
```

DRIVER.BAS

TIMBER AND STEEL

```
10 KEY OFF
20 CLS
30 LOCATE 2,16:PRINT STRING$(50,223)
40 LOCATE 1,15:PRINT STRING$(52,223)
50 LOCATE 6,16:PRINT STRING$(50,220)
60 LOCATE 7,15:PRINT STRING$(52,220)
70 FOR I=2 TO 6:LOCATE I,16:PRINT STRING$(1,221):
   LOCATE I,66:PRINT STRING$(1,222):NEXT I
80 FOR I=1 TO 7:LOCATE I,15:PRINT STRING$(1,221):
   LOCATE I,67:PRINT STRING$(1,222):NEXT I
90 LOCATE 4,2:PRINT STRING$(13,219):LOCATE 4,68:
   PRINT STRING$(10,219)
100 LOCATE 23,2:PRINT STRING$(76,219)
110 FOR I=4 TO 23:LOCATE I,2:PRINT STRING$(1,219):
    LOCATE I,78:PRINT STRING$(1,219):NEXT I
120 LOCATE 3,22:PRINT"    WATERFRONT FACILITY INSPECTION    "
130 LOCATE 4,22:PRINT"         FREQUENCY GENERATOR          "
140 LOCATE 9,30:PRINT" SELECTION MENU"
150 LOCATE 10,30:PRINT"----------------"
160 LOCATE 12,30:PRINT" 1) TIMBER "
170 LOCATE 14,30:PRINT" 2) STEEL (H-PILES)"
180 LOCATE 16,30:PRINT" 3) STEEL (SHEET PILES)"
190 LOCATE 18,30:PRINT" 4) EXIT PROGRAM"
200 LOCATE 20,33:PRINT" Selection:     "
210 A$=INKEY$:IF A$="" THEN 210
220 X2X=INSTR("1234",A$):COLOR 31,0
230 ON X2X GOTO 270,310,350,390
240 LOCATE 20,24:PRINT "NOT A VALID SELECTION; TRY AGAIN":BEEP
250 LOCATE 20,24
260 FOR I=1 TO 1000: I=I+1:NEXT:
    PRINT"                                        ": GOTO 200
270 LOCATE 20,26:PRINT"*  Processing has begun  *"
280 LOCATE 20,51
290 OPEN "1.111" AS 1
300 SYSTEM
310 LOCATE 20,26:PRINT"*  Processing has begun  *"
320 COLOR 0,0:LOCATE 20,51
330 OPEN "2.222" AS 1
340 SYSTEM
350 LOCATE 20,26:PRINT"*  Processing has begun  *"
360 LOCATE 20,51
370 OPEN "3.333" AS 1
380 SYSTEM
390 LOCATE 20,26:PRINT"*  Processing has begun  *"
400 LOCATE 20,51
410 OPEN "4.444" AS 1
420 CLS
430 SYSTEM
```

CONCRETE

```
10 KEY OFF
20 CLS
30 LOCATE 2,16:PRINT STRING$(50,223)
40 LOCATE 1,15:PRINT STRING$(52,223)
50 LOCATE 6,16:PRINT STRING$(50,220)
60 LOCATE 7,15:PRINT STRING$(52,220)
70 FOR I=2 TO 6:LOCATE I,16:PRINT STRING$(1,221):
   LOCATE I,66:PRINT STRING$(1,222):NEXT I
80 FOR I=1 TO 7:LOCATE I,15:PRINT STRING$(1,221):
   LOCATE I,67:PRINT STRING$(1,222):NEXT I
90 LOCATE 4,2:PRINT STRING$(13,219):LOCATE 4,68:
   PRINT STRING$(10,219)
100 LOCATE 23,2:PRINT STRING$(76,219)
110 FOR I=4 TO 23:LOCATE I,2:PRINT STRING$(1,219):
    LOCATE I,78:PRINT STRING$(1,219):NEXT I
120 LOCATE 3,22:PRINT"    WATERFRONT FACILITY INSPECTION   "
130 LOCATE 4,22:PRINT"         FREQUENCY GENERATOR         "
140 LOCATE 9,30:PRINT" SELECTION MENU"
150 LOCATE 10,30:PRINT"----------------"
160 LOCATE 14,30:PRINT" 1) CONCRETE "
200 LOCATE 16,30:PRINT" 2) EXIT PROGRAM"
210 LOCATE 20,33:PRINT" Selection:     "
220 A$=INKEY$:IF A$="" THEN 220
230 X2X=INSTR("12",A$):COLOR 31,0
240 ON X2X GOTO 280,320
250 LOCATE 20,24:PRINT "NOT A VALID SELECTION; TRY AGAIN":BEEP
260 LOCATE 20,24
270 FOR I=1 TO 1000: I=I+1:NEXT:
    PRINT"                                       ": GOTO 210
280 LOCATE 20,26:PRINT"*  Processing has begun  *"
290 LOCATE 20,51
300 OPEN "1.111" AS 1
310 SYSTEM
320 LOCATE 20,26:PRINT"*  Processing has begun  *"
330 COLOR 0,0:LOCATE 20,51
340 OPEN "2.222" AS 1
345 CLS
350 SYSTEM
```

PTIM.FOR

```
C
C  PROGRAM TO DETERMINE OPTIMAL INSPECTION FREQUENCY FOR TIMBER
C  FACILITIES BASED ON EXPECTED ANNUAL COSTS
C
      REAL ODIAM,OAREA
      INTEGER AGE
      PI=3.14159265
C
 901  DO 14 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                                    '
  14  CONTINUE
      DO 24 I=9,22
      CALL CUP(I,13)
      WRITE(*,*)'                                                              '
  24  CONTINUE
      CALL CUP(3,17)
      WRITE(*,*)'                  TIMBER'
      CALL CUP(4,17)
      WRITE(*,*)'       SELECT ONE OF THE FOLLOWING OPTIONS'
      CALL CUP(5,17)
      WRITE(*,*)'      -------------------------------------'
      CALL CUP(10,20)
      WRITE(*,*)' 1)  REVIEW DETERIORATION COEFFICIENTS'
      CALL CUP(11,20)
      WRITE(*,*)' 2)  REVIEW INSPECTION COST DATA'
      CALL CUP(12,20)
      WRITE(*,*)' 3)  REVIEW REPAIR COST DATA'
      CALL CUP(13,20)
      WRITE(*,*)' 4)  REVIEW FAILURE COST DATA'
      CALL CUP(14,20)
      WRITE(*,*)' 5)  REVIEW SAMPLING CRITERIA'
      CALL CUP(15,20)
      WRITE(*,*)' 6)  REVIEW THRESHOLD VALUES'
      CALL CUP(16,20)
      WRITE(*,*)' 7)  GENERATE INSPECTION FREQUENCIES'
      CALL CUP(18,30)
      WRITE(*,*)'SELECTION: ___'
      CALL CUP(18,43)
      READ(*,*) ISELECT
      IF(ISELECT.EQ.1) GOTO 1001
      IF(ISELECT.EQ.2) GOTO 2001
      IF(ISELECT.EQ.3) GOTO 3001
      IF(ISELECT.EQ.4) GOTO 4001
      IF(ISELECT.EQ.5) GOTO 5001
      IF(ISELECT.EQ.6) GOTO 6001
      IF(ISELECT.EQ.7) GOTO 7001
C
C  MODIFY DETERIORATION RATE COEFFICIENTS
C
 1001 OPEN(28,FILE='DETCOEF',STATUS='OLD')
      READ(28,301) RATE,RATESD
      DO 15 I=3,5
      CALL CUP(I,17)
```

```
      WRITE(*,*)'
  15  CONTINUE
      DO 25 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
  25  CONTINUE
      CALL CUP(4,17)
      WRITE(*,*)'           DETERIORATION COEFFICIENT'
      CALL CUP(5,17)
      WRITE(*,*)'          ---------------------------'
      CALL CUP(11,14)
      WRITE(*,*)'THE CURRENT MEAN COEFFICIENT IS:'
      CALL CUP(11,52)
      WRITE(*,'(F8.6)') RATE
      CALL CUP(13,14)
      WRITE(*,*)'THE CURRENT S.D. COEFFICIENT IS:'
      CALL CUP(13,52)
      WRITE(*,'(F8.6)') RATESD
 777  CALL CUP(17,10)
      WRITE(*,*)'     DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,58)
      READ(*,'(A1)',ERR=777)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 231
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 1001
 231  CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)'ENTER THE NEW MEAN COEFFICIENT'
      CALL CUP(17,52)
      WRITE(*,*)'__________'
      CALL CUP(17,53)
      READ(*,*) RATE1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER THE NEW S.D. COEFFICIENT'
      CALL CUP(19,52)
      WRITE(*,*)'__________'
      CALL CUP(19,53)
      READ(*,*) RATESD1
      REWIND(28)
      WRITE(28,301) RATE1,RATESD1
 301  FORMAT(2F8.6)
      CLOSE(28,STATUS='KEEP')
      GOTO 901
C
C  MODIFY INSPECTION COSTS
C
 2001 OPEN(29,FILE='TINSPECT',STATUS='OLD')
      READ(29,302) VISCST,CALPCST
      DO 16 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
  16  CONTINUE
      DO 26 I=9,22
      CALL CUP(I,10)
```

```
      WRITE(*,*)'
   26 CONTINUE
      CALL CUP(4,19)
      WRITE(*,*)'                INSPECTION COSTS'
      CALL CUP(5,19)
      WRITE(*,*)'               ------------------'
      CALL CUP(11,14)
      WRITE(*,*)'LEVEL 1 INSPECTION COST: $'
      CALL CUP(11,52)
      WRITE(*,'(F8.2)') VISCST
      CALL CUP(13,14)
      WRITE(*,*)'LEVEL 2 OR 3 INSPECTION COST: $'
      CALL CUP(13,52)
      WRITE(*,'(F8.2)') CALPCST
  778 CALL CUP(17,10)
      WRITE(*,*)'      DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,58)
      READ(*,'(A1)',ERR=778)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 241
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 2001
  241 CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)'ENTER LEVEL 1 INSPECTION COST: $'
      CALL CUP(17,54)
      WRITE(*,*)'__________'
      CALL CUP(17,55)
      READ(*,*) VISCST1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER LEVEL 2 OR 3 INSPECTION COST: $'
      CALL CUP(19,54)
      WRITE(*,*)'__________'
      CALL CUP(19,55)
      READ(*,*) CALPCST1
      REWIND(29)
      WRITE(29,302) VISCST1,CALPCST1
  302 FORMAT(2F8.2)
      CLOSE(29,STATUS='KEEP')
      GOTO 901
C
C  MODIFY REPAIR COSTS
C
 3001 OPEN(37,FILE='TREPAIR',STATUS='OLD')
      READ(37,303) CSTWRAP,CSTJACK
      DO 17 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
   17 CONTINUE
      DO 27 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
   27 CONTINUE
      CALL CUP(4,19)
      WRITE(*,*)'                   REPAIR COSTS'
```

```
      CALL CUP(5,19)
      WRITE(*,*)'                -------------'
      CALL CUP(11,9)
      WRITE(*,*)'     CURRENT WRAPPING COST: $'
      CALL CUP(11,52)
      WRITE(*,'(F8.2)') CSTWRAP
      CALL CUP(13,9)
      WRITE(*,*)'     CURRENT JACKETING COST: $'
      CALL CUP(13,52)
      WRITE(*,'(F8.2)') CSTJACK
 779  CALL CUP(17,10)
      WRITE(*,*)'     DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,58)
      READ(*,'(A1)',ERR=779)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 251
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 3001
 251  CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)'ENTER THE WRAPPING COST: $'
      CALL CUP(17,53)
      WRITE(*,*)'__________'
      CALL CUP(17,54)
      READ(*,*) CSTWRAP1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER THE JACKETING COST: $'
      CALL CUP(19,53)
      WRITE(*,*)'__________'
      CALL CUP(19,54)
      READ(*,*) CSTJACK1
      REWIND(37)
      WRITE(37,303) CSTWRAP1,CSTJACK1
 303  FORMAT(2F8.2)
      CLOSE(37,STATUS='KEEP')
      GOTO 901
C
C  MODIFY FAILURE COSTS
C
 4001 OPEN(38,FILE='TFAILURE',STATUS='OLD')
      READ(38,304) CSTREPL,CSTLOST,CSTLIFE,CSTUSE
      DO 18 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
  18  CONTINUE
      DO 28 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
  28  CONTINUE
      CALL CUP(4,19)
      WRITE(*,*)'                 FAILURE COSTS'
      CALL CUP(5,19)
      WRITE(*,*)'                --------------'
      CALL CUP(11,9)
      WRITE(*,*)'     CURRENT REPLACEMENT COST: $'
```

```
      CALL CUP(11,57)
      WRITE(*,'(F8.2)') CSTREPL
      CALL CUP(12,9)
      WRITE(*,*)'     CURRENT COST OF LOST EQUIPMENT: $'
      CALL CUP(12,57)
      WRITE(*,'(F8.2)') CSTLOST
      CALL CUP(13,9)
      WRITE(*,*)'     CURRENT COST OF LOST LIFE: $'
      CALL CUP(13,57)
      WRITE(*,'(F8.2)') CSTLIFE
      CALL CUP(14,9)
      WRITE(*,*)'     CURRENT COST OF LOSS OF FACILITY USE: $'
      CALL CUP(14,57)
      WRITE(*,'(F8.2)') CSTUSE
 780  CALL CUP(17,10)
      WRITE(*,*)'     DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,58)
      READ(*,'(A1)',ERR=780)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 261
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 4001
 261  CALL CUP(17,10)
      WRITE(*,*)'                                                 '
      CALL CUP(17,14)
      WRITE(*,*)'ENTER THE REPLACEMENT COST: $'
      CALL CUP(17,57)
      WRITE(*,*)'_________'
      CALL CUP(17,58)
      READ(*,*) CSTREPL1
      CALL CUP(18,14)
      WRITE(*,*)'ENTER THE EQUIPMENT COST: $'
      CALL CUP(18,57)
      WRITE(*,*)'_________'
      CALL CUP(18,58)
      READ(*,*) CSTLOST1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER THE COST OF LOST LIFE: $'
      CALL CUP(19,57)
      WRITE(*,*)'_________'
      CALL CUP(19,58)
      READ(*,*) CSTLIFE1
      CALL CUP(20,14)
      WRITE(*,*)'ENTER THE COST OF FACILITY USE: $'
      CALL CUP(20,57)
      WRITE(*,*)'_________'
      CALL CUP(20,58)
      READ(*,*) CSTUSE1
      REWIND(38)
      WRITE(38,304) CSTREPL1,CSTLOST1,CSTLIFE1,CSTUSE1
 304  FORMAT(4F8.2)
      CLOSE(38,STATUS='KEEP')
      GOTO 901
C
C  MODIFY SAMPLING CRITERIA
C
```

```
 5001 OPEN(44,FILE='TSAMPLE',STATUS='OLD')
      READ(44,607) CONLEV,DESACC
      DO 73 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
   73 CONTINUE
      DO 74 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
  74  CONTINUE
      CALL CUP(4,19)
      WRITE(*,*)'                  SAMPLING CRITERIA'
      CALL CUP(5,19)
      WRITE(*,*)'                  -------------------'
      CALL CUP(11,9)
      WRITE(*,*)'      CURRENT CONFIDENCE LEVEL'
      CALL CUP(11,52)
      WRITE(*,'(F5.3)') CONLEV
      CALL CUP(13,9)
      WRITE(*,*)'      CURRENT DESIRED ACCURACY'
      CALL CUP(13,52)
      WRITE(*,'(F5.3)') DESACC
 679  CALL CUP(17,10)
      WRITE(*,*)'     DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___
      CALL CUP(17,57)
      READ(*,'(A1)',ERR=679)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 371
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 5001
 371  CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)'ENTER NEW CONFIDENCE LEVEL'
      CALL CUP(18,14)
      WRITE(*,*)' (0.90, 0.95, 0.98 OR 0.99)'
      CALL CUP(18,53)
      WRITE(*,*)'_________'
      CALL CUP(18,54)
      READ(*,*) CONLEV1
      CALL CUP(20,14)
      WRITE(*,*)'ENTER DESIRED ACCURACY'
      CALL CUP(21,14)
      WRITE(*,*)'(0.01 TO 0.20)'
      CALL CUP(21,53)
      WRITE(*,*)'_________'
      CALL CUP(21,54)
      READ(*,*) DESACC1
      REWIND(44)
      WRITE(44,607) CONLEV1,DESACC1
 607  FORMAT(2F5.3)
      CLOSE(44,STATUS='KEEP')
      GOTO 901
C
C  MODIFY THRESHOLD VALUES
C
```

```
6001 OPEN(45,FILE='THRESH',STATUS='OLD')
     READ(45,608) TUP,TMID,TLOW
     DO 71 I=3,5
     CALL CUP(I,17)
     WRITE(*,*)'
  71 CONTINUE
     DO 72 I=9,22
     CALL CUP(I,10)
     WRITE(*,*)'
 72  CONTINUE
     CALL CUP(4,19)
     WRITE(*,*)'            THRESHOLD VALUES'
     CALL CUP(5,19)
     WRITE(*,*)'           ------------------'
     CALL CUP(11,9)
     WRITE(*,*)'     CURRENT WRAPPING THRESHOLD'
     CALL CUP(11,52)
     WRITE(*,'(F5.3)') TUP
     CALL CUP(12,9)
     WRITE(*,*)'     CURRENT JACKETING THRESHOLD'
     CALL CUP(12,52)
     WRITE(*,'(F5.3)') TMID
     CALL CUP(13,9)
     WRITE(*,*)'     CURRENT REPLACEMENT THRESHOLD'
     CALL CUP(13,52)
     WRITE(*,'(F5.3)') TLOW
680  CALL CUP(17,10)
     WRITE(*,*)'    DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
     CALL CUP(17,57)
     READ(*,'(A1)',ERR=680)ANS1
     IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 372
     IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
     GOTO 6001
372  CALL CUP(17,10)
     WRITE(*,*)'
     CALL CUP(17,14)
     WRITE(*,*)'ENTER WRAPPING THRESHOLD'
     CALL CUP(17,53)
     WRITE(*,*)'_________'
     CALL CUP(17,54)
     READ(*,*) TUP1
     CALL CUP(18,14)
     WRITE(*,*)'ENTER JACKETING THRESHOLD'
     CALL CUP(18,53)
     WRITE(*,*)'_________'
     CALL CUP(18,54)
     READ(*,*) TMID1
     CALL CUP(19,14)
     WRITE(*,*)'ENTER REPLACEMENT THRESHOLD'
     CALL CUP(19,53)
     WRITE(*,*)'_________'
     CALL CUP(19,54)
     READ(*,*) TLOW1
     REWIND(45)
     WRITE(45,608) TUP1,TMID1,TLOW1
```

```
 608   FORMAT(3F5.3)
       CLOSE(45,STATUS='KEEP')
       GOTO 901
C
C   OUTPUT OPTION SCREEN
C
 7001 IKI=7
      IDO=2
 111   DO 181 I=3,5
       CALL CUP(I,17)
       WRITE(*,*)'
 181   CONTINUE
       DO 19 J=9,20
       CALL CUP(J,16)
       WRITE(*,*)'
  19   CONTINUE
       CALL CUP(4,17)
       WRITE(*,*)'     INSPECTION FREQUENCIES FOR TIMBER PILES'
       CALL CUP(5,17)
       WRITE(*,*)'    -----------------------------------------'
       CALL CUP(9,10)
       WRITE(*,*)'                          OUTPUT OPTIONS    '
       CALL CUP(10,10)
       WRITE(*,*)'                         ----------------    '
       CALL CUP(12,10)
       WRITE(*,*)'                        1) OUTPUT TO SCREEN'
       CALL CUP(13,10)
       WRITE(*,*)'                        2) OUTPUT TO PRINTER'
       CALL CUP(14,10)
       WRITE(*,*)'                        3) OUTPUT TO BOTH   '
  222 CALL CUP(16,10)
       WRITE(*,*)'                             OPTION:___        '
       IJK=0
       CALL CUP(16,43)
       READ(*,'(I1)',ERR=222)IOP
       IF(IOP.LT.1.OR.IOP.GT.3)GOTO 222
       IF(IOP.EQ.2.OR.IOP.EQ.3)THEN
       CALL CUP(18,10)
       WRITE(*,*)'     *** CHECK TO SEE IF PRINTER IS PROPERLY CONNECTED *
     +**'
       CALL CUP(19,10)
       WRITE(*,*)'        IF PRINTER IS NOT CONNECTED PROGRAM WILL ABORT'
       DO 225 IJ=1,7000
       IDO=IDO/IJ*3
 225   CONTINUE
       CALL CUP(18,10)
       WRITE(*,*)'
     +  '
       CALL CUP(19,10)
       WRITE(*,*)'                                                       '
  133 CALL CUP(18,10)
       WRITE(*,*)'          IS THE PRINTER PROPERLY CONNECTED (Y/N)?___  '
       CALL CUP(18,62)
       READ(*,'(A1)',ERR=133)ANS
       IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')GOTO 131
```

```
      IF(ANS.EQ.'N'.OR.ANS.EQ.'n')GOTO 223
      GOTO 133
  223 CALL CUP(19,10)
      WRITE(*,*)'          *** NO PRINTER IS CONNECTED TO SYSTEM ***'
      CALL CUP(20,1)
      PAUSE
      GOTO 111
      ENDIF
C
  131 CALL CUP(3,25)
      DO 57 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
  57  CONTINUE
      DO 58 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'                                                           '
  58  CONTINUE
C
C  DATA INPUT SCREEN
C
      CALL CUP(4,28)
      WRITE(*,'(A)')'ENTER THE FOLLOWING DATA'
      CALL CUP(5,27)
      WRITE(*,*)'-----------------------'
      CALL CUP(11,16)
      WRITE(*,'(A)')'AGE OF PIER'
      CALL CUP(12,16)
      WRITE(*.'(A)')'NUMBER OF PILES IN PIER'
      CALL CUP(13,16)
      WRITE(*,'(A)')'DESIGN PILE DIAMETER (IN.)'
      CALL CUP(14,16)
      WRITE(*,'(A)')'FINAL MEAN PILE DIAMETER (IN.)'
      CALL CUP(15,16)
      WRITE(*,'(A)')'FINAL S.D. OF PILE DIAMETER (IN)'
      CALL CUP(16,16)
      WRITE(*,'(A)')'AGE AT WHICH DETERIORATION BEGINS'
      CALL CUP(17,16)
      WRITE(*,'(A)')'FACTOR OF SAFETY (DEFAULT 2.0)'
      CALL CUP(11,55)
      WRITE(*,*)'______'
      CALL CUP(11,56)
      READ(*,'(I4)') AGE
      CALL CUP(12,55)
      WRITE(*,*)'______'
      CALL CUP(12,56)
      READ(*,'(I4)') NUM
      CALL CUP(13,55)
      WRITE(*,*)'______'
      CALL CUP(13,56)
      READ(*,*) ODIAM
      CALL CUP(14,55)
      WRITE(*,*)'______'
      CALL CUP(14,56)
      READ(*,*) RMEAN
```

```
      CALL CUP(15,55)
      WRITE(*,*)'______
      CALL CUP(15,56)
      READ(*,*) SD
      CALL CUP(16,55)
      WRITE(*,*)'______
      CALL CUP(16,56)
      READ(*,'(I4)') NUMAGE
      CALL CUP(17,55)
      WRITE(*,*)'______
      CALL CUP(17,56)
      READ(*,'(F7.4)') FACTOR
      IF(FACTOR .EQ. 0.0)FACTOR=2.0
C
C  OPEN EXISTING DATA INPUT FILES AND CREATE OUTPUT HEADING
C
      CALL ED
      OPEN(28,FILE='DETCOEF',STATUS='OLD')
      OPEN(29,FILE='TINSPECT',STATUS='OLD')
      OPEN(37,FILE='TREPAIR',STATUS='OLD')
      OPEN(38,FILE='TFAILURE',STATUS='OLD')
      OPEN(44,FILE='TSAMPLE',STATUS='OLD')
      OPEN(45,FILE='THRESH',STATUS='OLD')
      READ(28,'(2F8.6)') RATE,RATESD
      READ(29,'(2F8.2)') VISCST,CALPCST
      READ(37,'(2F8.2)') CSTWRAP,CSTJACK
      READ(38,'(4F8.2)') CSTREPL,CSTLOST,CSTLIFE,CSTUSE
      READ(44,'(2F5.3)') CONLEV,DESACC
      READ(45,'(3F5.3)') TUP,TMID,TLOW
      CALL CUP(3,0)
      IF(IOP.EQ.1.OR.IOP.EQ.3)THEN
      WRITE(*,'(A)')'                              EXPECTED ANNUAL COSTS'
      WRITE(*,*)
      WRITE(*,'(A)')'   INSPECTION       INSPECTION         REPAIR
     + FAILURE          TOTAL'
      CALL CUP(6,0)
      WRITE(*,'(A)')'     PERIOD             COST              COST
     +  COST            COST'
      CALL CUP(7,0)
      WRITE(*,'(A)')'   -----------------------------------------------
     +----------------------'
      ENDIF
C
C  PRODUCE HARDCOPY OF INPUT VALUES
C
      IF(IOP.EQ.2.OR.IOP.EQ.3)THEN
      OPEN(9,FILE='LPT1')
      WRITE(9,*)
      WRITE(9,*)
      WRITE(9,'(28X,A20)')'TIMBER INPUT VALUES'
      WRITE(9,*)
      WRITE(9,'(5X,A50,F16.6)')'MEAN COEFFICIENT:
     +          ',RATE
      WRITE(9,'(5X,A50,F16.6)')'STANDARD DEV. COEF:
     +          ',RATESD
```

```
      WRITE(9,'(5X,A50,F12.2)')'LEVEL 1 INSPECTION COST:
     +         ',VISCST
      WRITE(9,'(5X,A50,F12.2)')'LEVEL 2 OR 3 INSPECTION COST:
     +         ',CALPCST
      WRITE(9,'(5X,A50,F12.2)')'WRAPPING COST:
     +         ',CSTWRAP
      WRITE(9,'(5X,A50,F12.2)')'JACKETING COST:
     +         ',CSTJACK
      WRITE(9,'(5X,A50,F12.2)')'REPLACEMENT COST:
     +         ',CSTREPL
      WRITE(9,'(5X,A50,F12.2)')'EQUIPMENT LOSS COST:
     +         ',CSTLOST
      WRITE(9,'(5X,A50,F12.2)')'LOSS OF LIFE COST:
     +         ',CSTLIFE
      WRITE(9,'(5X,A50,F12.2)')'LOSS OF USE COST:
     +         ',CSTUSE
      WRITE(9,'(5X,A50,F12.2)')'CONFIDENCE LEVEL:
     +         ',CONLEV
      WRITE(9,'(5X,A50,F12.2)')'DESIRED ACCURACY:
     +         ',DESACC
      WRITE(9,'(5X,A50,F12.2)')'WRAPPING THRESHOLD:
     +         ',TUP
      WRITE(9,'(5X,A50,F12.2)')'JACKETING THRESHOLD:
     +         ',TMID
      WRITE(9,'(5X,A50,F12.2)')'REPLACEMENT THRESHOLD:
     +         ',TLOW
      WRITE(9,'(5X,A55,I4)')'AGE OF PIER:
     +              ',AGE
      WRITE(9,'(5X,A55,I4)')'NUMBER OF PILES IN PIER:
     +              ',NUM
      WRITE(9,'(5X,A50,F12.2)')'DESIGN PILE DIAMETER (IN):
     +         ',ODIAM
      WRITE(9,'(5X,A50,F12.2)')'MEAN PILE DIAMETER (IN):
     +         ',RMEAN
      WRITE(9,'(5X,A50,F12.2)')'S.D. OF PILE DIAMETER (IN):
     +         ',SD
      WRITE(9,'(5X,A55,I4)')'AGE AT WHICH DETERIORATION BEGINS:
     +              ',NUMAGE
      WRITE(9,'(5X,A50,F12.2)')'FACTOR OF SAFETY:
     +         ',FACTOR
      WRITE(9,*)
      WRITE(9,*)
      WRITE(9,'(27X,A22)')'EXPECTED ANNUAL COSTS'
      WRITE(9,*)
      WRITE(9,*)'INSPECTION     INSPECTION          REPAIR         FAILURE
     +         TOTAL'
      WRITE(9,*)'  PERIOD          COST              COST            COST
     +         COST'
      WRITE(9,*)'-------------------------------------------------------
     +--------------'
      ENDIF
C
C  CALCULATE PILE DIAMETER THRESHOLD VALUES
C
      LKL=9
```

```
      SMEAN=3.1939+(0.8838*ODIAM)
      FAREA1=PI*((SMEAN/2.0)**2)
      THRWRAP=(SQRT((FAREA1*TUP)/PI))*2.0
      THRJACK=(SQRT((FAREA1*TMID)/PI))*2.0
      THRREPL=(SQRT((FAREA1*TLOW)/PI))*2.0
C
C   DETERMINES INTERSECTION POINT
C
      TSMEAN=3.1939+(0.8838*ODIAM)
      NAUM=(NINT((RMEAN-TSMEAN)/(-(RATE))))
      NBUM=AGE-NAUM
      IF(NBUM.LT.NUMAGE) THEN
       NCUM=NUMAGE
      ENDIF
C
C   BEGIN LOOP
C
      DO 40 J5=1,25
      NUMWRAP=0
      NUMJACK=0
      NUMREPL=0
C
C   CALCULATES WRAPPING, JACKETING, AND REPLACEMENT PROBABILITIES
C   IF FACILITY AGE LESS THAN AGE THAT PILE DETERIORATION BEGINS
C
      IF(AGE.LT.NCUM) THEN
       PW=0.0
       PJ=0.0
       PR=0.0
      ENDIF
C
C   CALCULATES PROBABILITY OF ACCIDENTAL PILE FAILURE
C
      IF(AGF 3E.NCUM) THEN
      CALL  .ILURE(DELTAT,RMEAN,SD,PI,PROBFAIL,FACTOR,FAREA,OAREA,TMEAN,
     +ODIAM)
      NUMFAIL=NINT(FLOAT(NUM)*PROBFAIL)
C
C   CALCULATES WRAPPING, JACKETING, AND REPLACEMENT PROBABILITIES
C   IF FACILITY AGE MORE THAN AGE THAT PILE DETERIORATION BEGINS
C
      DO 117 II=1,3
      IF(II.EQ.1) THEN
        BETA=(THRWRAP-RMEAN)/SD
        IF(BETA.LT.-5.0) BETA=-5.0
      ENDIF
      IF(II.EQ.2) THEN
        BETA=(THRJACK-RMEAN)/SD
        IF(BETA.LT.-5.0) BETA=-5.0
      ENDIF
      IF(II.EQ.3) THEN
        BETA=(THRREPL-RMEAN)/SD
        IF(BETA.LT.-5.0) BETA=-5.0
      ENDIF
      CALL NORMDIST(BETA,PI,G)
```

```
C
      IF(II.EQ.1) THEN
       G1=G
      ENDIF
C
      IF(II.EQ.2) THEN
       G2=G
      ENDIF
C
      IF(II.EQ.3) THEN
       G3=G
      ENDIF
C
C
C
  117 CONTINUE
C
      PW=G1-G2
      PJ=G2-G3
      PR=G3
C
C  CALCULATES EXPECTED NUMBER OF WRAPPED, JACKETED, AND REPLACED
C  PILES
C
      NREM=NUM-NUMFAIL
      NUMWRAP=NREM*PW
      NUMJACK=NREM*PJ
      NUMREPL=NREM*PR
C
C
C
      AVEWRAP=(FLOAT(NUMWRAP))
      AVEJACK=(FLOAT(NUMJACK))
      AVEREPL=(FLOAT(NUMREPL))
      AVEFAIL=(FLOAT(NUMFAIL))
      ENDIF
C
C  DETERMINES NUMBER OF PILES FOR LEVEL 2 OR 3 INSPECTION SAMPLE
C
      IF(CONLEV.EQ.0.90) Z1=1.645
      IF(CONLEV.EQ.0.95) Z1=1.96
      IF(CONLEV.EQ.0.98) Z1=2.326
      IF(CONLEV.EQ.0.99) Z1=2.576
C
      SAM1=(DESACC**2)*(FLOAT(NUM-1))
      SAM2=(Z1**2)*(SD/RMEAN)*(FLOAT(NUM))
      SAM3=1/FLOAT(NUM)
      SAM=1/((SAM1/SAM2)+SAM3)
      IF(SAM.LT.30.0) SAM=30.0
C
C  CALCULATES COSTS
C
      NUM1=NINT(SAM)
      NUM2=NUM-NUM1
      TICOST=((FLOAT(NUM2)*VISCST)+(FLOAT(NUM1)*CALPCST))/FLOAT(J5)
```

```
      TRCOST=((AVEJACK*CSTJACK)+(AVEWRAP*CSTWRAP)+(AVEREPL*CSTREPL))/
     +FLOAT(J5)
      TFCOST=(AVEFAIL*CSTREPL)+CSTLOST+CSTLIFE+CSTUSE
      TOTCOST=TICOST+TRCOST+TFCOST
C
C  CLEARS SCREEN
C
      LKL=LKL+1
      IF(J5.EQ.11.OR.J5.EQ.21.OR.J5.EQ.31) LKL=9
C
      IF(LKL .EQ. 9)THEN
       CALL CUP(22,22)
       WRITE(*,*)'PRESS THE <RETURN> KEY TO CONTINUE'
       CALL CUP(22,57)
       READ(*,'(A1)')COOL
       DO 666 JKJ=9,22
       CALL CUP(JKJ,0)
       WRITE(*,*)'
     +
  666 CONTINUE
      ENDIF
C
C  OUTPUT TO SCREEN
C
      CALL CUP(LKL,0)
      IF(IOP.EQ.1.OR.IOP.EQ.3) THEN
      WRITE(*,99) J5,TICOST,TRCOST,TFCOST,TOTCOST
 99   FORMAT(8X,I2,9X,F12.0,2X,F12.0,2X,F12.0,3X,F12.0)
      ENDIF
C
C  HARD COPY OUTPUT
C
      IF(IOP.EQ.2.OR.IOP.EQ.3) THEN
      WRITE(9,98) J5,TICOST,TRCOST,TFCOST,TOTCOST
 98   FORMAT(5X,I2,7X,F12.0,3X,F12.0,3X,F12.0,2X,F12.0)
      ENDIF
C
C  MODIFY DETERIORATION RATES AS AGE INCREASES
C
      IF(AGE.GE.NCUM) THEN
        RMEAN=RMEAN-RATE
        SD=SD+RATESD
      ENDIF
      AGE=AGE+1
 40   CONTINUE
C
C
      CALL CUP(20,20)
      WRITE(*,*)'PRESS THE <RETURN> KEY TO CONTINUE'
      CALL CUP(20,55)
      READ(*,'(A1)')COOL
      CALL ED
      END
C
C
```

```
C
C
C     THIS SUBROUTINE CALCULATES THE PROBABILITY OF INDIVIDUAL PILE
C     FAILURE BASED ON THE ORIGINAL MEAN PILE AREA, THE FINAL MEAN
C     PILE AREA AND THE COEFFICIENT OF VARIATION OF STRENGTH,
C     STRUCTURAL RESISTANCE, AND GEOMETRY.
C
C
      SUBROUTINE FAILURE(DELTAT,RMEAN,SD,PI,PROBFAIL,FACTOR,FAREA,OAREA,
     +TMEAN,ODIAM)
      REAL OAREA,ODIAM
      DF=0.2
      DG=SD/RMEAN
      DL=0.15
      DELTAT=SQRT(DF**2+DG**2+DL**2)
      TMEAN=3.1939+(0.8838*ODIAM)
        FAREA=PI*((RMEAN/2.0)**2)
        OAREA=PI*((TMEAN/2.0)**2)
        BETA=(ALOG(FACTOR*(FAREA/OAREA)))/DELTAT
      CALL NORMDIST(BETA,PI,G)
      PROBFAIL=1.0-G
      RETURN
      END
C
C
C
C
C     THIS SUBROUTINE CALCULATES THE CUMULATIVE NORMAL
C     DISTRIBUTION FOR EACH VALUE OF BETA OBTAINED IN THE
C     PREVIOUS SUBROUTINE.  THE CUMULATIVE VALUES ARE DERIVED
C     BY MEANS OF SIMPSON'S RULE.
C
C
      SUBROUTINE NORMDIST(BETA,PI,G)
      F(Z)=(1/(SQRT(2*PI)))*EXP(-(.5*Z**2))
      N2=40
      EN=N2
      DX=(BETA-(-5.0))/EN
      S=0.
      X=(-5.0)+DX
      I=1
      M=N2-1
      DO 6 J=1,M
      FX=F(X)
      S=S+FX
      GOTO (4,5),I
 4    S=S+FX
      I=2
      GOTO 3
 5    I=1
 3    X=X+DX
 6    CONTINUE
      G=(F(-5.0)+S+S+F(BETA))*DX/3.0
      RETURN
      END
```

PST.FOR

```
C
C  PROGRAM TO DETERMINE OPTIMUM INSPECTION FREQUENCY FOR STEEL
C  H-PILE SUPPORTED FACILITIES BASED ON EXPECTED ANNUAL COSTS
C
      INTEGER AGE
      PI=3.14159265
C
 901  DO 14 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
  14  CONTINUE
      DO 24 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
     +      '
  24  CONTINUE
      CALL CUP(3,17)
      WRITE(*,*)'                              STEEL
      CALL CUP(4,17)
      WRITE(*,*)'     SELECT ONE OF THE FOLLOWING OPTIONS
      CALL CUP(5,17)
      WRITE(*,*)'    ------------------------------------
      CALL CUP(10,20)
      WRITE(*,*)' 1)  REVIEW DETERIORATION COEFFICIENTS
      CALL CUP(11,20)
      WRITE(*,*)' 2)  REVIEW INSPECTION COST DATA'
      CALL CUP(12,20)
      WRITE(*,*)' 3)  REVIEW REPAIR COST DATA'
      CALL CUP(13,20)
      WRITE(*,*)' 4)  REVIEW FAILURE COST DATA'
      CALL CUP(14,20)
      WRITE(*,*)' 5)  REVIEW SAMPLING CRITERIA'
      CALL CUP(15,20)
      WRITE(*,*)' 6)  REVIEW THRESHOLD VALUES'
      CALL CUP(16,20)
      WRITE(*,*)' 7)  GENERATE INSPECTION FREQUENCIES'
      CALL CUP(18,30)
      WRITE(*,*)'SELECTION: ___'
      CALL CUP(18,43)
      READ(*,*) ISELECT
      IF(ISELECT.EQ.1) GOTO 1001
      IF(ISELECT.EQ.2) GOTO 2001
      IF(ISELECT.EQ.3) GOTO 3001
      IF(ISELECT.EQ.4) GOTO 4001
      IF(ISELECT.EQ.5) GOTO 5001
      IF(ISELECT.EQ.6) GOTO 6001
      IF(ISELECT.EQ.7) GOTO 7001
C
C  MODIFY DETERIORATION RATE COEFFICIENTS
C
 1001 OPEN(28,FILE='STCOEF',STATUS='OLD')
      READ(28,301) FLAMEAN,FLASD
      DO 15 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
```

```
 15   CONTINUE
      DO 25 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'                                                        '
 25   CONTINUE
      CALL CUP(4,17)
      WRITE(*,*)'          DETERIORATION COEFFICIENT'
      CALL CUP(5,17)
      WRITE(*,*)'         ---------------------------'
777   CALL CUP(11,14)
      WRITE(*,*)'THE CURRENT MEAN COEFFICIENT IS:'
      CALL CUP(11,56)
      WRITE(*,'(F8.6)') FLAMEAN
      CALL CUP(13,14)
      WRITE(*,*)'THE CURRENT S.D. COEFFICIENT IS:'
      CALL CUP(13,56)
      WRITE(*,'(F8.6)') FLASD
      CALL CUP(17,14)
      WRITE(*,*)'   DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,60)
      READ(*,'(A1)',ERR=777)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 231
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 1001
231   CALL CUP(17,10)
      WRITE(*,*)'                                                      '
      CALL CUP(17,14)
      WRITE(*,*)'ENTER THE NEW MEAN COEFFICIENT'
      CALL CUP(17,56)
      WRITE(*,*)'__________'
      CALL CUP(17,57)
      READ(*,*) FLAMEAN1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER THE NEW S.D. COEFFICIENT'
      CALL CUP(19,56)
      WRITE(*,*)'__________'
      CALL CUP(19,57)
      READ(*,*) FLASD1
      REWIND(28)
      WRITE(28,301) FLAMEAN1,FLASD1
301   FORMAT(2F8.6)
      CLOSE(28,STATUS='KEEP')
      GOTO 901
C
C  MODIFY INSPECTION COSTS
C
2001  OPEN(29,FILE='SINSPECT',STATUS='OLD')
      READ(29,302) STCSTA,STCSTB
      DO 16 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                                   '
 16   CONTINUE
      DO 26 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
```

```
     +
 26   CONTINUE
      CALL CUP(4,19)
      WRITE(*,*)'                INSPECTION COSTS'
      CALL CUP(5,19)
      WRITE(*,*)'               ------------------'
 778  CALL CUP(11,10)
      WRITE(*,*)'    CURRENT LEVEL 1 INSPECTION COST: $'
      CALL CUP(11,56)
      WRITE(*,'(F8.2)') STCSTA
      CALL CUP(13,10)
      WRITE(*,*)'    CURRENT LEVEL 2 OR 3 INSPECTION COST: $'
      CALL CUP(13,56)
      WRITE(*,'(F8.2)') STCSTB
      CALL CUP(17,14)
      WRITE(*,*)'  DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,59)
      READ(*,'(A1)',ERR=778)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 241
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 2001
 241  CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)'ENTER LEVEL 1 INSPECTION COST: $'
      CALL CUP(17,59)
      WRITE(*,*)'_________'
      CALL CUP(17,60)
      READ(*,*) STCSTA1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER LEVEL 2 OR 3 INSPECTION COST: $'
      CALL CUP(19,59)
      WRITE(*,*)'_________'
      CALL CUP(19,60)
      READ(*,*) STCSTB1
      REWIND(29)
      WRITE(29,302) STCSTA,STCSTB
 302  FORMAT(2F8.2)
      CLOSE(29,STATUS='KEEP')
      GOTO 901
C
C  MODIFY REPAIR COSTS
C
 3001 OPEN(37,FILE='SREPAIR',STATUS='OLD')
      READ(37,303) CSTSTEL
      DO 17 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
 17   CONTINUE
      DO 27 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
     +       '
 27   CONTINUE
      CALL CUP(4,17)
```

```
      WRITE(*,*)'                              REPAIR COSTS'
      CALL CUP(5,17)
      WRITE(*,*)'                             --------------'
  779 CALL CUP(11,14)
      WRITE(*,*)'   CURRENT COST FOR REPAIR: $'
      CALL CUP(11,56)
      WRITE(*,'(F8.2)') CSTSTEL
      CALL CUP(17,14)
      WRITE(*,*)'     DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___
      CALL CUP(17,62)
      READ(*,'(A1)',ERR=779)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 251
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 3001
 251  CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)'   ENTER THE REPAIR COST: $'
      CALL CUP(17,56)
      WRITE(*,*)'__________'
      CALL CUP(17,57)
      READ(*,*) CSTSTEL1
      REWIND(37)
      WRITE(37,303) CSTSTEL1
 303  FORMAT(F8.2)
      CLOSE(37,STATUS='KEEP')
      GOTO 901
C
C  MODIFY FAILURE COSTS
C
 4001 OPEN(38,FILE='SFAILURE',STATUS='OLD')
      READ(38,304) CSTREPL,CSTLOST,CSTLIFE,CSTUSE
      DO 18 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
  18  CONTINUE
      DO 28 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
     +     '
  28  CONTINUE
      CALL CUP(4,17)
      WRITE(*,*)'                              FAILURE COSTS'
      CALL CUP(5,17)
      WRITE(*,*)'                             ---------------'
  780 CALL CUP(11,14)
      WRITE(*,*)' CURRENT REPLACEMENT COST: $'
      CALL CUP(11,56)
      WRITE(*,'(F12.2)') CSTREPL
      CALL CUP(12,14)
      WRITE(*,*)' CURRENT COST OF LOST EQUIPMENT: $'
      CALL CUP(12,56)
      WRITE(*,'(F12.2)') CSTLOST
      CALL CUP(13,14)
      WRITE(*,*)' CURRENT COST OF LOST LIFE: $'
```

```
      CALL CUP(13,56)
      WRITE(*,'(F12.2)') CSTLIFE
      CALL CUP(14,14)
      WRITE(*,*)' CURRENT COST OF LOSS OF FACILITY USE: $'
      CALL CUP(14,56)
      WRITE(*,'(F12.2)') CSTUSE
      CALL CUP(17,14)
      WRITE(*,*)'       DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___
      CALL CUP(17,62)
      READ(*,'(A1)',ERR=780)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 261
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 4001
 261  CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)' ENTER THE REPLACEMENT COST: $'
      CALL CUP(17,61)
      WRITE(*,*)'_________'
      CALL CUP(17,62)
      READ(*,*) CSTREPL1
      CALL CUP(18,14)
      WRITE(*,*)' ENTER THE EQUIPMENT COST: $'
      CALL CUP(18,61)
      WRITE(*,*)'_________'
      CALL CUP(18,62)
      READ(*,*) CSTLOST1
      CALL CUP(19,14)
      WRITE(*,*)' ENTER THE COST OF LOST LIFE: $'
      CALL CUP(19,61)
      WRITE(*,*)'_________'
      CALL CUP(19,62)
      READ(*,*) CSTLIFE1
      CALL CUP(20,14)
      WRITE(*,*)' ENTER THE COST OF FACILITY USE: $'
      CALL CUP(20,61)
      WRITE(*,*)'_________'
      CALL CUP(20,62)
      READ(*,*) CSTUSE1
      REWIND(38)
      WRITE(38,304) CSTREPL1,CSTLOST1,CSTLIFE1,CSTUSE1
 304  FORMAT(4F12.2)
      CLOSE(38,STATUS='KEEP')
      GOTO 901
C
C  MODIFY SAMPLING CRITERIA
C
 5001 OPEN(44,FILE='SSAMPLE',STATUS='OLD')
      READ(44,607) CONLEV,DESACC
      DO 73 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
   73 CONTINUE
      DO 74 I=9,22
      CALL CUP(I,10)
```

```
      WRITE(*,*)'                                                    '
 74   CONTINUE
      CALL CUP(4,19)
      WRITE(*,*)'                       SAMPLING CRITERIA'
      CALL CUP(5,19)
      WRITE(*,*)'                      -------------------'
      CALL CUP(11,9)
      WRITE(*,*)'     CURRENT CONFIDENCE LEVEL'
      CALL CUP(11,52)
      WRITE(*,'(F5.3)') CONLEV
      CALL CUP(13,9)
      WRITE(*,*)'     CURRENT DESIRED ACCURACY'
      CALL CUP(13,52)
      WRITE(*,'(F5.3)') DESACC
679   CALL CUP(17,10)
      WRITE(*,*)'    DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,57)
      READ(*,'(A1)',ERR=679)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 371
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 5001
371   CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)'ENTER NEW CONFIDENCE LEVEL'
      CALL CUP(18,14)
      WRITE(*,*)' (0.90, 0.95, 0.98 OR 0.99)'
      CALL CUP(18,53)
      WRITE(*,*)'_________'
      CALL CUP(18,54)
      READ(*,*) CONLEV1
      CALL CUP(20,14)
      WRITE(*,*)'ENTER DESIRED ACCURACY'
      CALL CUP(21,14)
      WRITE(*,*)'(0.01 TO 0.20)'
      CALL CUP(21,53)
      WRITE(*,*)'_________'
      CALL CUP(21,54)
      READ(*,*) DESACC1
      REWIND(44)
      WRITE(44,607) CONLEV1,DESACC1
607   FORMAT(2F5.3)
      CLOSE(44,STATUS='KEEP')
      GOTO 901
C
C  MODIFY THRESHOLD VALUES
C
6001  OPEN(45,FILE='SHRESH',STATUS='OLD')
      READ(45,608) SUP,SLOW
      DO 71 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
  71  CONTINUE
      DO 72 I=9,22
      CALL CUP(I,10)
```

```
      WRITE(*,*)'                                                            '
 72   CONTINUE
      CALL CUP(4,19)
      WRITE(*,*)'           THRESHOLD VALUES'
      CALL CUP(5,19)
      WRITE(*,*)'           ------------------'
      CALL CUP(11,9)
      WRITE(*,*)'     CURRENT REPAIR THRESHOLD'
      CALL CUP(11,52)
      WRITE(*,'(F5.3)') SUP
      CALL CUP(13,9)
      WRITE(*,*)'     CURRENT REPLACEMENT THRESHOLD'
      CALL CUP(13,52)
      WRITE(*,'(F5.3)') SLOW
680   CALL CUP(17,10)
      WRITE(*,*)'    DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,57)
      READ(*,'(A1)',ERR=680)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 372
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 6001
372   CALL CUP(17,10)
      WRITE(*,*)'                                                        '
      CALL CUP(17,14)
      WRITE(*,*)'ENTER REPAIR THRESHOLD'
      CALL CUP(17,53)
      WRITE(*,*)'_________'
      CALL CUP(17,54)
      READ(*,*) SUP1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER REPLACEMENT THRESHOLD'
      CALL CUP(19,53)
      WRITE(*,*)'_________'
      CALL CUP(19,54)
      READ(*,*) SLOW1
      REWIND(45)
      WRITE(45,608) SUP1,SLOW1
608   FORMAT(2F5.3)
      CLOSE(45,STATUS='KEEP')
      GOTO 901
C
C  OUTPUT OPTION SCREEN
C
7001  IKI=7
      IDO=2
111   DO 181 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                                      '
181   CONTINUE
      DO 19 J=9,20
      CALL CUP(J,16)
      WRITE(*,*)'                                                        '
 19   CONTINUE
      CALL CUP(4,17)
      WRITE(*,*)'    INSPECTION FREQUENCIES FOR STEEL PILES'
```

```
      CALL CUP(5,17)
      WRITE(*,*)'    ----------------------------------------'
      CALL CUP(9,10)
      WRITE(*,*)'                      OUTPUT OPTIONS    '
      CALL CUP(10,10)
      WRITE(*,*)'                     ----------------    '
      CALL CUP(12,10)
      WRITE(*,*)'                   1) OUTPUT TO SCREEN'
      CALL CUP(13,10)
      WRITE(*,*)'                   2) OUTPUT TO PRINTER'
      CALL CUP(14,10)
      WRITE(*,*)'                   3) OUTPUT TO BOTH   '
  222 CALL CUP(16,10)
      WRITE(*,*)'                         OPTION:___        '
      IJK=0
      CALL CUP(16,43)
      READ(*,'(I1)',ERR=222) IOP
      IF(IOP.LT.1.OR.IOP.GT.3)GOTO 222
      IF(IOP.EQ.2.OR.IOP.EQ.3)THEN
      CALL CUP(18,10)
      WRITE(*,*)'     *** CHECK TO SEE IF PRINTER IS PROPERLY CONNECTED *
     +**'
      CALL CUP(19,10)
      WRITE(*,*)'        IF PRINTER IS NOT CONNECTED PROGRAM WILL ABORT'
      DO 225 IJ=1,7000
      IDO=IDO/IJ*3
 225  CONTINUE
      CALL CUP(18,10)
      WRITE(*,*)'
     +  '
      CALL CUP(19,10)
      WRITE(*,*)'                                                      '
  133 CALL CUP(18,10)
      WRITE(*,*)'           IS THE PRINTER PROPERLY CONNECTED (Y/N)?___ '
      CALL CUP(18,62)
      READ(*,'(A1)',ERR=133) ANS
      IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')GOTO 131
      IF(ANS.EQ.'N'.OR.ANS.EQ.'n')GOTO 223
      GOTO 133
  223 CALL CUP(19,10)
      WRITE(*,*)'          *** NO PRINTER IS CONNECTED TO SYSTEM ***'
      CALL CUP(20,1)
      PAUSE
      GOTO 111
      ENDIF
C
 131  DO 57 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                                 '
  57  CONTINUE
      DO 58 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'                                                       '
  58  CONTINUE
C
```

```
C  DATA INPUT SCREENS
C
      CALL CUP(4,29)
      WRITE(*,*)'ENTER THE FOLLOWING DATA'
      CALL CUP(5,29)
      WRITE(*,*)'------------------------'
      CALL CUP(11,16)
      WRITE(*,'(A)')'AGE OF PIER'
      CALL CUP(12,16)
      WRITE(*,'(A)')'NUMBER OF PILES IN PIER'
      CALL CUP(13,16)
      WRITE(*,'(A)')'ORIGINAL MEAN PILE AREA (SQ. IN.)'
      CALL CUP(14,16)
      WRITE(*,'(A)')'FINAL MEAN THICKNESS (IN.)'
      CALL CUP(15,16)
      WRITE(*,'(A)')'FINAL S.D. OF THICKNESS (IN.)'
      CALL CUP(11,55)
      WRITE(*,*)'______'
      CALL CUP(11,56)
      READ(*,'(I2)') AGE
      CALL CUP(12,55)
      WRITE(*,*)'______'
      CALL CUP(12,56)
      READ(*,'(I4)') NUM
      CALL CUP(13,55)
      WRITE(*,*)'______'
      CALL CUP(13,56)
      READ(*,*) STEELOR
      CALL CUP(14,55)
      WRITE(*,*)'______'
      CALL CUP(14,56)
      READ(*,*) TFMEAN
      CALL CUP(15,55)
      WRITE(*,*)'______'
      CALL CUP(15,56)
      READ(*,*) SDTF
      DO 76 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
   76 CONTINUE
      DO 77 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
   77 CONTINUE
      CALL CUP(4,29)
      WRITE(*,*)'ENTER THE FOLLOWING DATA'
      CALL CUP(5,29)
      WRITE(*,*)'------------------------'
      CALL CUP(12,16)
      WRITE(*,'(A)')'BOF MEASUREMENT (IN.)'
      CALL CUP(13,16)
      WRITE(*,'(A)')'DOB MEASUREMENT (IN.)'
      CALL CUP(14,16)
      WRITE(*,'(A)')'AGE AT WHICH DETERIORATION BEGINS'
      CALL CUP(15,16)
```

```
      WRITE(*,'(A)')'FACTOR OF SAFETY (DEFAULT 2.0)'
      CALL CUP(12,55)
      WRITE(*,*)'______'
      CALL CUP(12,56)
      READ(*,*) BOF
      CALL CUP(13,55)
      WRITE(*,*)'______'
      CALL CUP(13,56)
      READ(*,*) DOB
      CALL CUP(14,55)
      WRITE(*,*)'______'
      CALL CUP(14,56)
      READ(*,'(I4)') NUMAGE
      CALL CUP(15,55)
      WRITE(*,*)'______'
      CALL CUP(15,56)
      READ(*,'(F7.4)') FACTOR
      IF(FACTOR .EQ. 0.0)FACTOR=2.0
C
C  OPEN EXISTING DATA INPUT FILES AND CREATE OUTPUT HEADING
C
      CALL ED
      OPEN(28,FILE='STCOEF',STATUS='OLD')
      OPEN(29,FILE='SINSPECT',STATUS='OLD')
      OPEN(37,FILE='SREPAIR',STATUS='OLD')
      OPEN(38,FILE='SFAILURE',STATUS='OLD')
      OPEN(44,FILE='SSAMPLE',STATUS='OLD')
      OPEN(45,FILE='SHRESH',STATUS='OLD')
      READ(28,'(2F8.6)') FLAMEAN,FLASD
      READ(29,'(2F8.2)') STCSTA,STCSTB
      READ(37,'(F8.2)') CSTSTEL
      READ(38,'(4F12.2)') CSTREPL,CSTLOST,CSTLIFE,CSTUSE
      READ(44,'(2F5.3)') CONLEV,DESACC
      READ(45,'(2F5.3)') SUP,SLOW
      CALL CUP(3,0)
      IF(IOP.EQ.1.OR.IOP.EQ.3)THEN
      WRITE(*,'(A)')'                          EXPECTED ANNUAL COSTS'
      WRITE(*,*)
      WRITE(*,'(A)')'    INSPECTION       INSPECTION         REPAIR
     + FAILURE          TOTAL'
      CALL CUP(6,0)
      WRITE(*,'(A)')'      PERIOD             COST               COST
     +  COST            COST'
      CALL CUP(7,0)
      WRITE(*,'(A)')'    ----------------------------------------------
     +-------------------------'
      ENDIF
C
C  PRODUCE HARD COPY OF INPUT VALUES
C
      IF(IOP.EQ.2.OR.IOP.EQ.3)THEN
      OPEN(9,FILE='LPT1')
      WRITE(9,*)
      WRITE(9,*)
      WRITE(9,'(24X,A)')'STEEL INPUT VALUES'
```

```
 WRITE(9,*)
 WRITE(9,'(5X,A50,F16.6)')'MEAN COEFFICIENT:
+          ',FLAMEAN
 WRITE(9,'(5X,A50,F16.6)')'ST. DEV. COEF:
+          ',FLASD
 WRITE(9,'(5X,A50,F12.2)')'LEVEL 1 INSPECTION COST:
+          ',STCSTA
 WRITE(9,'(5X,A50,F12.2)')'LEVEL 2 OR 3 INSPECTION COST:
+          ',STCSTB
 WRITE(9,'(5X,A50,F12.2)')'REPAIR COST:
+          ',CSTSTEL
 WRITE(9,'(5X,A50,F12.2)')'REPLACEMENT COST:
+          ',CSTREPL
 WRITE(9,'(5X,A50,F12.2)')'EQUIPMENT LOSS COST:
+          ',CSTLOST
 WRITE(9,'(5X,A50,F12.2)')'LOSS OF LIFE COST:
+          ',CSTLIFE
 WRITE(9,'(5X,A50,F12.2)')'LOSS OF USE COST:
+          ',CSTUSE
 WRITE(9,'(5X,A50,F13.3)')'CONFIDENCE LEVEL:
+          ',CONLEV
 WRITE(9,'(5X,A50,F13.3)')'DESIRED ACCURACY:
+          ',DESACC
 WRITE(9,'(5X,A50,F13.3)')'WRAPPING THRESHOLD:
+          ',SUP
 WRITE(9,'(5X,A50,F13.3)')'REPLACEMENT THRESHOLD:
+          ',SLOW
 WRITE(9,'(5X,A55,I4)')'AGE OF PIER:
+               ',AGE
 WRITE(9,'(5X,A55,I4)')'NUMBER OF PILES IN PIER:
+               ',NUM
 WRITE(9,'(5X,A50,F13.3)')'ORIGINAL MEAN PILE AREA (SQ. IN.):
+               ',STEELOR
 WRITE(9,'(5X,A50,F13.3)')'FINAL MEAN THICKNESS (IN.):
+               ',TFMEAN
 WRITE(9,'(5X,A50,F13.3)')'FINAL S.D. OF THICKNESS (IN.):
+               ',SDTF
 WRITE(9,'(5X,A50,F13.3)')'BOF MEASUREMENT (IN.):
+               ',BOF
 WRITE(9,'(5X,A50,F13.3)')'DOB MEASUREMENT (IN.):
+               ',DOB
 WRITE(9,'(5X,A55,I4)')'AGE AT WHICH DETERIORATION BEGINS:
+               ',NUMAGE
 WRITE(9,'(5X,A50,F12.2)')'FACTOR OF SAFETY:
+          ',FACTOR
 WRITE(9,*)
 WRITE(9,*)
 WRITE(9,'(27X,A23)')'EXPECTED ANNUAL COSTS'
 WRITE(9,*)
 WRITE(9,*)'INSPECTION     INSPECTION        REPAIR        FAILURE
+         TOTAL'
 WRITE(9,*)'  PERIOD          COST             COST          COST
+         COST'
 WRITE(9,*)'-------------------------------------------------------------
--------------'
```

```
      ENDIF
C
C  CALCULATE PILE AREA THRESHOLD VALUES
C
      LKL=9
      THRFIX=STEELOR*SUP
      THRREPL=STEELOR*SLOW
C
C  DETERMINES INTERSECTION POINT
C
      NAUM=(NINT((TFMEAN-FLATHK)/(-(FLAMEAN))))
      NBUM=AGE-NAUM
      IF(NBUM.LT.NUMAGE) THEN
       NCUM=NUMAGE
      ENDIF
C
C  BEGIN LOOP
C
      DO 40 J5=1,25
      NUMFIX=0
      NUMREPL=0
      NUMFAIL=0
C
C  CALCULATES REPAIR AND REPLACEMENT PROBABILITIES IF FACILITY
C  AGE LESS THAN AGE THAT PILE DETERIORATION BEGINS
C
      IF(AGE.LT.NCUM) THEN
       PF=0.0
       PR=0.0
       DBF=DOB-(2*TFMEAN)
       SDAREA=(SQRT(((2*BOF)**2)+(DBF**2)))*SDTF
       STAREA=((2*(BOF*TFMEAN))+(DBF*TFMEAN))
      ENDIF
C
C  CALCULATES PROBABILITY OF ACCIDENTAL PILE FAILURE
C
      IF(AGE.GE.NCUM) THEN
      CALL FAILURE(DELTAT,PI,PROBFAIL,FACTOR,TFMEAN,SDTF,STEELOR,SDAREA
     +,STAREA,BOF,DOB)
      NUMFAIL=NINT(FLOAT(NUM)*PROBFAIL)
C
C  CALCULTES REPAIR AND REPLACEMENT PROBABILITIES IF FACILITY
C  AGE MORE THAN AGE THAT PILE DETERIORATION BEGINS
C
      DO 117 II=1,2
      IF(II.EQ.1) BETA=(THRFIX-STAREA)/SDAREA
      IF(II.EQ.2) BETA=(THRREPL-STAREA)/SDAREA
      CALL NORMDIST(BETA,PI,G)
C
      IF(II.EQ.1) THEN
       G1=G
      ENDIF
C
      IF(II.EQ.2) THEN
       G2=G
```

```
      ENDIF
C
C
C
  117 CONTINUE
C
      PF=G1-G2
      PR=G2
C
C  CALCULATES EXPECTED NUMBER OF REPAIRED AND REPLACED PILES
C
      NREM=NUM-NUMFAIL
      NUMFIX=NREM*PF
      NUMREPL=NREM*PR
C
C
C
      AVEFIX=(FLOAT(NUMFIX))
      AVEREPL=(FLOAT(NUMREPL))
      AVEFAIL=(FLOAT(NUMFAIL))
      ENDIF
C
C  DETERMINES NUMBER OF PILES FOR LEVEL 2 OR 3 INSPECTION SAMPLE
C
C
      IF(CONLEV.EQ.0.90) Z1=1.645
      IF(CONLEV.EQ.0.95) Z1=1.96
      IF(CONLEV.EQ.0.98) Z1=2.326
      IF(CONLEV.EQ.0.99) Z1=2.576
C
      SAM1=(DESACC**2)*(FLOAT(NUM-1))
      SAM2=(Z1**2)*(SDAREA/STAREA)*(FLOAT(NUM))
      SAM3=1/FLOAT(NUM)
      SAM=1/((SAM1/SAM2)+SAM3)
      IF(SAM.LT.30.0) SAM=30.0
C
C  CALCULATES COSTS
C
      NUM1=NINT(SAM)
      NUM2=NUM-NUM1
      SICOST=((FLOAT(NUM2)*STCSTA)+(FLOAT(NUM1)*STCSTB))/FLOAT(J5)
      SRCOST=((AVEFIX*CSTSTEL)+(AVEREPL*CSTREPL))/FLOAT(J5)
      SFCOST=(AVEFAIL*CSTREPL)+CSTLOST+CSTLIFE+CSTUSE
      TOTCOST=SICOST+SRCOST+SFCOST
C
C  CLEARS SCREEN
C
      LKL=LKL+1
      IF(J5.EQ.11.OR.J5.EQ.21.OR.J5.EQ.31) LKL=9
C
      IF(LKL .EQ. 9)THEN
       CALL CUP(22,22)
       WRITE(*,*)'PRESS THE <RETURN> KEY TO CONTINUE'
       CALL CUP(22,57)
       READ(*,'(A1)')COOL
```

```
        DO 666 JKJ=9,22
        CALL CUP(JKJ,0)
        WRITE(*,*)'
     +                                       '
  666 CONTINUE
      ENDIF
C
C  OUTPUT TO SCREEN
C
      CALL CUP(LKL,0)
      IF(IOP.EQ.1.OR.IOP.EQ.3) THEN
      WRITE(*,99) J5,SICOST,SRCOST,SFCOST,TOTCOST
 99   FORMAT(8X,I2,9X,F12.0,2X,F12.0,2X,F12.0,3X,F12.0)
      ENDIF
C
C  HARD COPY OUTPUT
C
      IF(IOP.EQ.2.OR.IOP.EQ.3) THEN
      WRITE(9,98) J5,SICOST,SRCOST,SFCOST,TOTCOST
 98   FORMAT(5X,I2,7X,F12.0,3X,F12.0,3X,F12.0,2X,F12.0)
      ENDIF
C
C  MODIFY DETERIORATION RATES AS AGE INCREASES
C
      IF(AGE.GE.NCUM) THEN
        TFMEAN=TFMEAN-FLAMEAN
        SDTF=SDTF+FLASD
      ENDIF
      AGE=AGE+1
 40   CONTINUE
C
C
      CALL CUP(20,20)
      WRITE(*,*)'PRESS THE <RETURN> KEY TO CONTINUE'
      CALL CUP(20,55)
      READ(*,'(A1)')COOL
      CALL ED
      END
C
C
C
C
C     THIS SUBROUTINE CALCULATES THE PROBABILITY OF INDIVIDUAL PILE
C     FAILURE BASED ON THE ORIGINAL MEAN PILE AREA, THE FINAL MEAN
C     PILE AREA AND THE COEFFICIENT OF VARIATION OF STRENGTH,
C     STRUCTURAL RESISTANCE, AND GEOMETRY.
C
C
      SUBROUTINE FAILURE(DELTAT,PI,PROBFAIL,FACTOR,TFMEAN,SDTF,STEELOR,S
     +DAREA,STAREA,BOF,DOB)
      DF=0.08
      DBF=DOB-(2*TFMEAN)
      SDAREA=(SQRT(((2*BOF)**2)+(DBF**2)))*SDTF
      STAREA=((2*(BOF*TFMEAN))+(DBF*TFMEAN))
      DG=(SDAREA/STAREA)
```

```
      DL=0.15
      DELTAT=SQRT(DF**2+DG**2+DL**2)
      BETA=(ALOG(FACTOR*(STAREA/STEELOR)))/DELTAT
      CALL NORMDIST(BETA,PI,G)
      PROBFAIL=1.0-G
      RETURN
      END
C
C
C
C
C     THIS SUBROUTINE CALCULATES THE CUMULATIVE NORMAL
C     DISTRIBUTION FOR EACH VALUE OF BETA OBTAINED IN THE
C     PREVIOUS SUBROUTINE.  THE CUMULATIVE VALUES ARE DERIVED
C     BY MEANS OF SIMPSON'S RULE.
C
C
      SUBROUTINE NORMDIST(BETA,PI,G)
      F(Z)=(1/(SQRT(2*PI)))*EXP(-(.5*Z**2))
      N2=40
      EN=N2
      DX=(BETA-(-5.0))/EN
      S=0.
      X=(-5.0)+DX
      I=1
      M=N2-1
      DO 6 J=1,M
      FX=F(X)
      S=S+FX
      GOTO (4,5),I
  4   S=S+FX
      I=2
      GOTO 3
  5   I=1
  3   X=X+DX
  6   CONTINUE
      G=(F(-5.0)+S+S+F(BETA))*DX/3.0
      RETURN
      END
```

S.FOR

```
C
C  PROGRAM TO DETERMINE OPTIMUM INSPECTION FREQUENCY FOR STEEL
C  SHEET PILE FACILITIES BASED ON EXPECTED ANNUAL COSTS
C
      INTEGER AGE
      PI=3.14159265
C
 901  DO 14 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                                 '
  14  CONTINUE
      DO 24 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
     +      '
  24  CONTINUE
      CALL CUP(3,17)
      WRITE(*,*)'                              STEEL'
      CALL CUP(4,17)
      WRITE(*,*)'      SELECT ONE OF THE FOLLOWING OPTIONS'
      CALL CUP(5,17)
      WRITE(*,*)'     -------------------------------------'
      CALL CUP(10,20)
      WRITE(*,*)' 1)  REVIEW DETERIORATION COEFFICIENTS'
      CALL CUP(11,20)
      WRITE(*,*)' 2)  REVIEW INSPECTION COST DATA'
      CALL CUP(12,20)
      WRITE(*,*)' 3)  REVIEW REPAIR COST DATA'
      CALL CUP(13,20)
      WRITE(*,*)' 4)  REVIEW FAILURE COST DATA'
      CALL CUP(14,20)
      WRITE(*,*)' 5)  REVIEW SAMPLING CRITERIA'
      CALL CUP(15,20)
      WRITE(*,*)' 6)  REVIEW THRESHOLD VALUES'
      CALL CUP(16,20)
      WRITE(*,*)' 7)  GENERATE INSPECTION FREQUENCIES'
      CALL CUP(18,30)
      WRITE(*,*)'SELECTION: ___'
      CALL CUP(18,43)
      READ(*,*) ISELECT
      IF(ISELECT.EQ.1) GOTO 1001
      IF(ISELECT.EQ.2) GOTO 2001
      IF(ISELECT.EQ.3) GOTO 3001
      IF(ISELECT.EQ.4) GOTO 4001
      IF(ISELECT.EQ.5) GOTO 5001
      IF(ISELECT.EQ.6) GOTO 6001
      IF(ISELECT.EQ.7) GOTO 7001
C
C  MODIFY DETERIORATION RATE COEFFICIENTS
C
 1001 OPEN(28,FILE='STCOEF',STATUS='OLD')
      READ(28,301) FLAMEAN,FLASD
      DO 15 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                                 '
```

```
 15   CONTINUE
      DO 25 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
 25   CONTINUE
      CALL CUP(4,17)
      WRITE(*,*)'          DETERIORATION COEFFICIENT'
      CALL CUP(5,17)
      WRITE(*,*)'         ---------------------------'
777   CALL CUP(11,14)
      WRITE(*,*)'THE CURRENT MEAN COEFFICIENT IS:'
      CALL CUP(11,56)
      WRITE(*,'(F8.6)') FLAMEAN
      CALL CUP(13,14)
      WRITE(*,*)'THE CURRENT S.D. COEFFICIENT IS:'
      CALL CUP(13,56)
      WRITE(*,'(F8.6)') FLASD
      CALL CUP(17,14)
      WRITE(*,*)'   DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,60)
      READ(*,'(A1)',ERR=777)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 231
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 1001
231   CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)'ENTER THE NEW MEAN COEFFICIENT'
      CALL CUP(17,56)
      WRITE(*,*)'_________'
      CALL CUP(17,57)
      READ(*,*) FLAMEAN1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER THE NEW S.D. COEFFICIENT'
      CALL CUP(19,56)
      WRITE(*,*)'_________'
      CALL CUP(19,57)
      READ(*,*) FLASD1
      REWIND(28)
      WRITE(28,301) FLAMEAN1,FLASD1
301   FORMAT(2F8.6)
      CLOSE(28,STATUS='KEEP')
      GOTO 901
C
C  MODIFY INSPECTION COSTS
C
2001 OPEN(29,FILE='SINSPECT',STATUS='OLD')
      READ(29,302) STCSTA,STCSTB
      DO 16 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
 16   CONTINUE
      DO 26 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
```

```
     +      '
  26  CONTINUE
      CALL CUP(4,19)
      WRITE(*,*)'            INSPECTION COSTS'
      CALL CUP(5,19)
      WRITE(*,*)'           ------------------'
  778 CALL CUP(11,10)
      WRITE(*,*)'    LEVEL 1 INSPECTION COST PER FOOT: $'
      CALL CUP(11,56)
      WRITE(*,'(F8.2)') STCSTA
      CALL CUP(13,10)
      WRITE(*,*)'    LEVEL 2 OR 3 INSPECTION COST PER SITE: $'
      CALL CUP(13,56)
      WRITE(*,'(F8.2)') STCSTB
      CALL CUP(17,14)
      WRITE(*,*)'  DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,59)
      READ(*,'(A1)',ERR=778)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 241
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 2001
 241  CALL CUP(17,10)
      WRITE(*,*)'                                                  '
      CALL CUP(17,14)
      WRITE(*,*)'ENTER LEVEL 1 INSPECTION COST: $'
      CALL CUP(17,59)
      WRITE(*,*)'_________'
      CALL CUP(17,60)
      READ(*,*) STCSTA1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER LEVEL 2 OR 3 INSPECTION COST: $'
      CALL CUP(19,59)
      WRITE(*,*)'_________'
      CALL CUP(19,60)
      READ(*,*) STCSTB1
      REWIND(29)
      WRITE(29,302) STCSTA,STCSTB
 302  FORMAT(2F8.2)
      CLOSE(29,STATUS='KEEP')
      GOTO 901
C
C  MODIFY REPAIR COSTS
C
 3001 OPEN(37,FILE='SREPAIR',STATUS='OLD')
      READ(37,303) CSTSTEL
      DO 17 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                             '
  17  CONTINUE
      DO 27 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
     +      '
  27  CONTINUE
      CALL CUP(4,17)
```

```
      WRITE(*,*)'                          REPAIR COSTS'
      CALL CUP(5,17)
      WRITE(*,*)'                         --------------'
  779 CALL CUP(11,14)
      WRITE(*,*)'   CURRENT COST FOR REPAIR: $'
      CALL CUP(11,56)
      WRITE(*,'(F8.2)') CSTSTEL
      CALL CUP(17,14)
      WRITE(*,*)'     DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,62)
      READ(*,'(A1)',ERR=779)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 251
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 3001
 251  CALL CUP(17,10)
      WRITE(*,*)'                                                            '
      CALL CUP(17,14)
      WRITE(*,*)'   ENTER THE REPAIR COST: $'
      CALL CUP(17,56)
      WRITE(*,*)'_________'
      CALL CUP(17,57)
      READ(*,*) CSTSTEL1
      REWIND(37)
      WRITE(37,303) CSTSTEL1
 303  FORMAT(F8.2)
      CLOSE(37,STATUS='KEEP')
      GOTO 901
C
C  MODIFY FAILURE COSTS
C
 4001 OPEN(38,FILE='SFAILURE',STATUS='OLD')
      READ(38,304) CSTREPL,CSTLOST,CSTLIFE,CSTUSE
      DO 18 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                                        '
  18  CONTINUE
      DO 28 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
     +      '
  28  CONTINUE
      CALL CUP(4,17)
      WRITE(*,*)'                          FAILURE COSTS'
      CALL CUP(5,17)
      WRITE(*,*)'                         ---------------'
  780 CALL CUP(11,14)
      WRITE(*,*)' CURRENT REPLACEMENT COST: $'
      CALL CUP(11,56)
      WRITE(*,'(F12.2)') CSTREPL
      CALL CUP(12,14)
      WRITE(*,*)' CURRENT COST OF LOST EQUIPMENT: $'
      CALL CUP(12,56)
      WRITE(*,'(F12.2)') CSTLOST
      CALL CUP(13,14)
      WRITE(*,*)' CURRENT COST OF LOST LIFE: $'
```

```
      CALL CUP(13,56)
      WRITE(*,'(F12.2)') CSTLIFE
      CALL CUP(14,14)
      WRITE(*,*)' CURRENT COST OF LOSS OF FACILITY USE: $'
      CALL CUP(14,56)
      WRITE(*,'(F12.2)') CSTUSE
      CALL CUP(17,14)
      WRITE(*,*)'     DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,62)
      READ(*,'(A1)',ERR=780)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 261
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 4001
 261  CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)' ENTER THE REPLACEMENT COST: $'
      CALL CUP(17,61)
      WRITE(*,*)'__________'
      CALL CUP(17,62)
      READ(*,*) CSTREPL1
      CALL CUP(18,14)
      WRITE(*,*)' ENTER THE EQUIPMENT COST: $'
      CALL CUP(18,61)
      WRITE(*,*)'__________'
      CALL CUP(18,62)
      READ(*,*) CSTLOST1
      CALL CUP(19,14)
      WRITE(*,*)' ENTER THE COST OF LOST LIFE: $'
      CALL CUP(19,61)
      WRITE(*,*)'__________'
      CALL CUP(19,62)
      READ(*,*) CSTLIFE1
      CALL CUP(20,14)
      WRITE(*,*)' ENTER THE COST OF FACILITY USE: $'
      CALL CUP(20,61)
      WRITE(*,*)'__________'
      CALL CUP(20,62)
      READ(*,*) CSTUSE1
      REWIND(38)
      WRITE(38,304) CSTREPL1,CSTLOST1,CSTLIFE1,CSTUSE1
 304  FORMAT(4F12.2)
      CLOSE(38,STATUS='KEEP')
      GOTO 901
C
C  MODIFY SAMPLING CRITERIA
C
 5001 OPEN(44,FILE='SSAMPLE',STATUS='OLD')
      READ(44,607) CONLEV,DESACC
      DO 73 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
   73 CONTINUE
      DO 74 I=9,22
      CALL CUP(I,10)
```

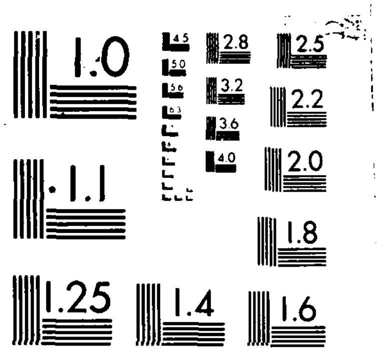
```
      WRITE(*,*)'
 74   CONTINUE
      CALL CUP(4,19)
      WRITE(*,*)'                SAMPLING CRITERIA'
      CALL CUP(5,19)
      WRITE(*,*)'                -------------------'
      CALL CUP(11,9)
      WRITE(*,*)'      CURRENT CONFIDENCE LEVEL'
      CALL CUP(11,52)
      WRITE(*,'(F5.3)') CONLEV
      CALL CUP(13,9)
      WRITE(*,*)'      CURRENT DESIRED ACCURACY'
      CALL CUP(13,52)
      WRITE(*,'(F5.3)') DESACC
679   CALL CUP(17,10)
      WRITE(*,*)'     DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___
      CALL CUP(17,57)
      READ(*,'(A1)',ERR=679)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 371
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 5001
371   CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)'ENTER NEW CONFIDENCE LEVEL
      CALL CUP(18,14)
      WRITE(*,*)' (0.90, 0.95, 0.98 OR 0.99,
      CALL CUP(18,53)
      WRITE(*,*)'_________'
      CALL CUP(18,54)
      READ(*,*) CONLEV1
      CALL CUP(20,14)
      WRITE(*,*)'ENTER DESIRED ACCURACY'
      CALL CUP(21,14)
      WRITE(*,*)'(0.01 TO 0.20)'
      CALL CUP(21,53)
      WRITE(*,*)'_________'
      CALL CUP(21,54)
      READ(*,*) DESACC1
      REWIND(44)
      WRITE(44,607) CONLEV1,DESACC1
607   FORMAT(2F5.3)
      CLOSE(44,STATUS='KEEP')
      GOTO 901
C
C  MODIFY THRESHOLD VALUES
C
6001  OPEN(45,FILE='SHRESH',STATUS='OLD')
      READ(45,608) SUP,SLOW
      DO 71 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
   71 CONTINUE
      DO 72 I=9,22
      CALL CUP(I,10)
```

```
      WRITE(*,*)'
 72   CONTINUE
      CALL CUP(4,19)
      WRITE(*,*)'                   THRESHOLD VALUES
      CALL CUP(5,19)
      WRITE(*,*)'                  ------------------
      CALL CUP(11,9)
      WRITE(*,*)'      CURRENT REPAIR THRESHOLD
      CALL CUP(11,52)
      WRITE(*,'(F5.3)') SUP
      CALL CUP(13,9)
      WRITE(*,*)'      CURRENT REPLACEMENT THRESHOLD'
      CALL CUP(13,52)
      WRITE(*,'(F5.3)') SLOW
680   CALL CUP(17,10)
      WRITE(*,*)'     DO YOU WISH TO CHANGE THESE VALUES (Y/N)' __
      CALL CUP(17,57)
      READ(*,'(A1)',ERR=680)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 372
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 6001
372   CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)'ENTER REPAIR THRESHOLD'
      CALL CUP(17,53)
      WRITE(*,*)'________
      CALL CUP(17,54)
      READ(*,*) SUP1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER REPLACEMENT THRESHOLD
      CALL CUP(19,53)
      WRITE(*,*)'________
      CALL CUP(19,54)
      READ(*,*) SLOW1
      REWIND(45)
      WRITE(45,608) SUP1,SLOW1
608   FORMAT(2F5.3)
      CLOSE(45,STATUS='KEEP'
      GOTO 901
C
C   OUTPUT OPTION SCREEN
C
7001  IKI=7
      IDO=2
111   DO 181 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
181   CONTINUE
      DO 19 J=9,20
      CALL CUP(J,16)
      WRITE(*,*)'
 19   CONTINUE
      CALL CUP(4,17)
      WRITE(*,*)'     INSPECTION FREQUENCIES FOR STEEL PILES'
```

```
      CALL CUP(5,17)
      WRITE(*,*)'    ----------------------------------------'
      CALL CUP(9,10)
      WRITE(*,*)'                  OUTPUT OPTIONS    '
      CALL CUP(10,10)
      WRITE(*,*)'                 ----------------   '
      CALL CUP(12,10)
      WRITE(*,*)'               1) OUTPUT TO SCREEN'
      CALL CUP(13,10)
      WRITE(*,*)'               2) OUTPUT TO PRINTER'
      CALL CUP(14,10)
      WRITE(*,*)'               3) OUTPUT TO BOTH  '
  222 CALL CUP(16,10)
      WRITE(*,*)'                    OPTION:___        '
      [illegible]
      CALL CUP(16,45)
      READ(*,'(I1)',ERR=222) IOP
      IF(IOP.LT.1.OR.IOP.GT.3)GOTO 222
      IF(IOP.EQ.2.OR.IOP.EQ.3)THEN
      CALL CUP(18,10)
      WRITE(*,*)'      *** CHECK TO SEE IF PRINTER IS PROPERLY CONNECTED *
     ***'
      CALL CUP(19,10)
      WRITE(*,*)'         IF PRINTER IS NOT CONNECTED PROGRAM WILL ABORT'
      [illegible]
      [illegible]
      CONTINUE
      CALL CUP(18,10)
      WRITE(*,*)'
     .'
      CALL CUP(19,10)
      WRITE(*,*)'                                                       '
      CALL CUP(18,10)
      WRITE(*,*)'          IS THE PRINTER PROPERLY CONNECTED (Y/N)?___  '
      CALL CUP(18,58)
      READ(*,'(A1)',ERR=133) ANS
      IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')GOTO 131
      IF(ANS.EQ.'N'.OR.ANS.EQ.'n')GOTO 223
      [illegible]
  223 CALL CUP(19,10)
      WRITE(*,*)'          *** NO PRINTER IS CONNECTED TO SYSTEM ***'
      CALL CUP(20,10)
      PAUSE
      GOTO 111
      ENDIF
C
  131 DO 57 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                                  '
   57 CONTINUE
      DO 58 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'                                                    '
   58 CONTINUE
C
```

AD-A176 878 INSPECTION FREQUENCY CRITERIA MODELS FOR TIMBER STEEL AND CONCRETE PILE S. (U) WESTERN INSTRUMENTS CORP VENTURA CA M CRIST DEC 86 NCEL-CR-87.005 2/2

UNCLASSIFIED N00123-86-D-0295 F/G 13/3 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

```
C  DATA INPUT SCREEN
C
      CALL CUP(4,29)
      WRITE(*,*)'ENTER THE FOLLOWING DATA'
      CALL CUP(5,29)
      WRITE(*,*)'------------------------'
      CALL CUP(10,16)
      WRITE(*,'(A)')'AGE OF PIER'
      CALL CUP(11,16)
      WRITE(*,'(A)')'NUMBER OF PILES IN PIER'
      CALL CUP(12,16)
      WRITE(*,'(A)')'ORIGINAL THICKNESS (IN.)'
      CALL CUP(13,16)
      WRITE(*,'(A)')'FINAL MEAN THICKNESS (IN.)'
      CALL CUP(14,16)
      WRITE(*,'(A)')'FINAL S.D. OF THICKNESS (IN.)'
      CALL CUP(15,16)
      WRITE(*,'(A)')'AGE AT WHICH DETERIORATION BEGINS'
      CALL CUP(16,16)
      WRITE(*,'(A)')'FACTOR OF SAFETY (DEFAULT 2.0)'
      CALL CUP(10,55)
      WRITE(*,*)'______'
      CALL CUP(10,56)
      READ(*,'(I2)') AGE
      CALL CUP(11,55)
      WRITE(*,*)'______'
      CALL CUP(11,56)
      READ(*,'(I4)') NUM
      CALL CUP(12,55)
      WRITE(*,*)'______'
      CALL CUP(12,56)
      READ(*,*) FLATHK
      CALL CUP(13,55)
      WRITE(*,*)'______'
      CALL CUP(13,56)
      READ(*,*) TFMEAN
      CALL CUP(14,55)
      WRITE(*,*)'______'
      CALL CUP(14,56)
      READ(*,*) SDTF
      CALL CUP(15,55)
      WRITE(*,*)'______'
      CALL CUP(15,56)
      READ(*,'(I4)') NUMAGE
      CALL CUP(16,55)
      WRITE(*,*)'______'
      CALL CUP(16,56)
      READ(*,'(F7.4)') FACTOR
      IF(FACTOR .EQ. 0.0)FACTOR=2.0
C
C  OPEN EXISTING DATA INPUT FILES AND CREATE OUTPUT HEADING
C
      CALL ED
      OPEN(28,FILE='STCOEF',STATUS='OLD')
      OPEN(29,FILE='SINSPECT',STATUS='OLD')
```

```
      OPEN(37,FILE='SREPAIR',STATUS='OLD')
      OPEN(38,FILE='SFAILURE',STATUS='OLD')
      OPEN(44,FILE='SSAMPLE',STATUS='OLD')
      OPEN(45,FILE='SHRESH',STATUS='OLD')
      READ(28,'(2F8.6)') FLAMEAN,FLASD
      READ(29,'(2F8.2)') STCSTA,STCSTB
      READ(37,'(F8.2)') CSTSTEL
      READ(38,'(4F12.2)') CSTREPL,CSTLOST,CSTLIFE,CSTUSE
      READ(44,'(2F5.3)') CONLEV,DESACC
      READ(45,'(2F5.3)') SUP,SLOW
      CALL CUP(3,0)
      IF(IOP.EQ.1.OR.IOP.EQ.3)THEN
      WRITE(*,'(A)')'                          EXPECTED ANNUAL COSTS
      WRITE(*,*)
      WRITE(*,'(A)')'    INSPECTION       INSPECTION        REPAIR
     + FAILURE          TOTAL'
      CALL CUP(6,0)
      WRITE(*,'(A)')'       PERIOD            COST              COST
     +  COST            COST'
      CALL CUP(7,0)
      WRITE(*,'(A)')'    -----------------------------------------------
     +------------------------'
      ENDIF
C
C  PRODUCE HARD COPY OF INPUT VALUES
C
      IF(IOP.EQ.2.OR.IOP.EQ.3)THEN
      OPEN(9,FILE='LPT1')
      WRITE(9,*)
      WRITE(9,*)
      WRITE(9,'(28X,A20)')'STEEL INPUT VALUES'
      WRITE(9,*)
      WRITE(9,'(5X,A50,F16.6)')'MEAN COEFFICIENT:
     +          ',FLAMEAN
      WRITE(9,'(5X,A50,F16.6)')'ST. DEV. COEF:
     +          ',FLASD
      WRITE(9,'(5X,A50,F12.2)')'LEVEL 1 INSPECTION COST:
     +          ',STCSTA
      WRITE(9,'(5X,A50,F12.2)')'LEVEL 2 OR 3 INSPECTION COST:
     +          ',STCSTB
      WRITE(9,'(5X,A50,F12.2)')'REPAIR COST:
     +          ',CSTSTEL
      WRITE(9,'(5X,A50,F12.2)')'REPLACEMENT COST:
     +          ',CSTREPL
      WRITE(9,'(5X,A50,F12.2)')'EQUIPMENT LOSS COST:
     +          ',CSTLOST
      WRITE(9,'(5X,A50,F12.2)')'LOSS OF LIFE COST:
     +          ',CSTLIFE
      WRITE(9,'(5X,A50,F12.2)')'LOSS OF USE COST:
     +          ',CSTUSE
      WRITE(9,'(5X,A50,F13.3)')'CONFIDENCE LEVEL:
     +          ',CONLEV
      WRITE(9,'(5X,A50,F13.3)')'DESIRED ACCURACY:
     +          ',DESACC
      WRITE(9,'(5X,A50,F13.3)')'WRAPPING THRESHOLD:
```

```
     +          ',SUP
      WRITE(9,'(5X,A50,F13.3)')'REPLACEMENT THRESHOLD:
     +          ',SLOW
      WRITE(9,'(5X,A55,I4)')'AGE OF PIER:
     +               ',AGE
      WRITE(9,'(5X,A55,I4)')'NUMBER OF PILES IN PIER:
     +               ',NUM
      WRITE(9,'(5X,A50,F13.3)')'ORIGINAL THICKNESS (IN.):
     +               ',FLATHK
      WRITE(9,'(5X,A50,F13.3)')'FINAL MEAN THICKNESS (IN.):
     +               ',TFMEAN
      WRITE(9,'(5X,A50,F13.3)')'FINAL S.D. OF THICKNESS (IN.):
     +               ',SDTF
      WRITE(9,'(5X,A55,I4)')'AGE AT WHICH DETERIORATION BEGINS:
     +               ',NUMAGE
      WRITE(9,'(5X,A50,F12.2)')'FACTOR OF SAFETY:
     +          ',FACTOR
      WRITE(9,*)
      WRITE(9,*)
      WRITE(9,'(27X,A23)')'EXPECTED ANNUAL COSTS'
      WRITE(9,*)
      WRITE(9,*)'INSPECTION     INSPECTION          REPAIR          FAILURE
     +         TOTAL'
      WRITE(9,*)'  PERIOD          COST              COST            COST
     +         COST'
      WRITE(9,*)'-----------------------------------------------------------
     +--------------'
      ENDIF
C
C  CALCULATE PILE THRESHOLD VALUES
C
      LKL=9
      STEELOR=FLATHK
      THRFIX=STEELOR*SUP
      THRREPL=STEELOR*SLOW
C
C  DETERMINE INTERSECTION POINT
C
      NAUM=(NINT((TFMEAN-FLATHK)/(-(FLAMEAN))))
      NBUM=AGE-NAUM
      IF(NBUM.LT.NUMAGE) THEN
       NCUM=NUMAGE
      ENDIF
C
C  BEGIN LOOP
C
      DO 40 J5=1,25
      NUMFIX=0
      NUMREPL=0
      NUMFAIL=0
C
C  CALCULATE REPAIR AND REPLACEMENT PROBABILITIES IF FACILITY
C  AGE LESS THAN AGE THAT PILE DETERIORATION BEGINS
C
      IF(AGE.LT.NCUM) THEN
```

```
         PF=0.0
         PR=0.0
         SDAREA=SDTF
         STAREA=TFMEAN
        ENDIF
C
C  CALCULATES PROBABILITY OF ACCIDENTAL PILE FAILURE
C
        IF(AGE.GE.NCUM) THEN
        CALL FAILURE(DELTAT,PI,PROBFAIL,FACTOR,STEELOR,SDAREA,STAREA,SDTF,
       +TFMEAN)
        NUMFAIL=NINT(FLOAT(NUM)*PROBFAIL)
C
C  CALCULATES REPAIR AND REPLACEMENT PROBABILITIES IF FACILITY
C  AGE MORE THAN AGE THAT PILE DETERIORATION BEGINS
C
        DO 117 II=1,2
        IF(II.EQ.1) BETA=(THRFIX-STAREA)/SDAREA
        IF(II.EQ.2) BETA=(THRREPL-STAREA)/SDAREA
        CALL NORMDIST(BETA,PI,G)
C
        IF(II.EQ.1) THEN
         G1=G
        ENDIF
C
        IF(II.EQ.2) THEN
         G2=G
        ENDIF
C
C
C
   117  CONTINUE
C
        PF=G1-G2
        PR=G2
C
C  CALCULATES EXPECTED NUMBER OF REPAIRED AND REPLACED PILES
C
        NREM=NUM-NUMFAIL
        NUMFIX=NREM*PF
        NUMREPL=NREM*PR
C
C
C
        AVEFIX=(FLOAT(NUMFIX))
        AVEREPL=(FLOAT(NUMREPL))
        AVEFAIL=(FLOAT(NUMFAIL))
        ENDIF
C
C  DETERMINES NUMBER OF PILES FOR LEVEL 2 OR 3 INSPECTION SAMPLE
C
C
        IF(CONLEV.EQ.0.90) Z1=1.645
        IF(CONLEV.EQ.0.95) Z1=1.96
        IF(CONLEV.EQ.0.98) Z1=2.326
```

```
      IF(CONLEV.EQ.0.99) Z1=2.576
C
      SAM1=(DESACC**2)*(FLOAT(NUM-1))
      SAM2=(Z1**2)*(SDAREA/STAREA)*(FLOAT(NUM))
      SAM3=1/FLOAT(NUM)
      SAM=1/((SAM1/SAM2)+SAM3)
      IF(SAM.LT.30.0) SAM=30.0
C
C  CALCULATES COSTS
C
      NUM1=NINT(SAM)
      NUM2=NUM-NUM1
      SICOST=((FLOAT(NUM2)*STCSTA)+(FLOAT(NUM1)*STCSTB))/FLOAT(J5)
      SRCOST=((AVEFIX*CSTSTEL)+(AVEREPL*CSTREPL))/FLOAT(J5)
      SFCOST=(AVEFAIL*CSTREPL)+CSTLOST+CSTLIFE+CSTUSE
      TOTCOST=SICOST+SRCOST+SFCOST
C
C  CLEARS SCREEN
C
      LKL=LKL+1
      IF(J5.EQ.11.OR.J5.EQ.21.OR.J5.EQ.31) LKL=9
C
      IF(LKL .EQ. 9)THEN
       CALL CUP(22,22)
       WRITE(*,*)'PRESS THE <RETURN> KEY TO CONTINUE'
       CALL CUP(22,57)
       READ(*,'(A1)')COOL
       DO 666 JKJ=9,22
       CALL CUP(JKJ,0)
       WRITE(*,*)'
     +                             '
  666 CONTINUE
      ENDIF
C
C  OUTPUT TO SCREEN
C
      CALL CUP(LKL,0)
      IF(IOP.EQ.1.OR.IOP.EQ.3) THEN
      WRITE(*,99) J5,SICOST,SRCOST,SFCOST,TOTCOST
 99   FORMAT(8X,I2,9X,F12.0,2X,F12.0,2X,F12.0,3X,F12.0)
      ENDIF
C
C  HARD COPY OUTPUT
C
      IF(IOP.EQ.2.OR.IOP.EQ.3) THEN
      WRITE(9,98) J5,SICOST,SRCOST,SFCOST,TOTCOST
 98   FORMAT(5X,I2,7X,F12.0,3X,F12.0,3X,F12.0,2X,F12.0)
      ENDIF
C
C  MODIFY DETERIORATION RATES AS AGE INCREASES
C
      IF(AGE.GE.NCUM) THEN
        TFMEAN=TFMEAN-FLAMEAN
        SDTF=SDTF+FLASD
      ENDIF
```

```
      AGE=AGE+1
 40   CONTINUE
C
C
      CALL CUP(20,20)
      WRITE(*,*)'PRESS THE <RETURN> KEY TO CONTINUE'
      CALL CUP(20,55)
      READ(*,'(A1)')COOL
      CALL ED
      END
C
C
C
C
C     THIS SUBROUTINE CALCULATES THE PROBABILITY OF INDIVIDUAL PILE
C     FAILURE BASED ON THE ORIGINAL MEAN PILE AREA, THE FINAL MEAN
C     PILE AREA AND THE COEFFICIENT OF VARIATION OF STRENGTH,
C     STRUCTURAL RESISTANCE, AND GEOMETRY.
C
C
      SUBROUTINE FAILURE(DELTAT,PI,PROBFAIL,FACTOR,STEELOR,SDAREA,STARE
     +A,SDTF,TFMEAN)
      SDAREA=SDTF
      STAREA=TFMEAN
      DF=0.08
      DG=(SDAREA/STAREA)
      DL=0.15
      DELTAT=SQRT(DF**2+DG**2+DL**2)
      BETA=(ALOG(FACTOR*(STAREA/STEELOR)))/DELTAT
      CALL NORMDIST(BETA,PI,G)
      PROBFAIL=1.0-G
      RETURN
      END
C
C
C
C
C     THIS SUBROUTINE CALCULATES THE CUMULATIVE NORMAL
C     DISTRIBUTION FOR EACH VALUE OF BETA OBTAINED IN THE
C     PREVIOUS SUBROUTINE.  THE CUMULATIVE VALUES ARE DERIVED
C     BY MEANS OF SIMPSON'S RULE.
C
C
      SUBROUTINE NORMDIST(BETA,PI,G)
      F(Z)=(1/(SQRT(2*PI)))*EXP(-(.5*Z**2))
      N2=40
      EN=N2
      DX=(BETA-(-5.0))/EN
      S=0.
      X=(-5.0)+DX
      I=1
      M=N2-1
      DO 6 J=1,M
      FX=F(X)
      S=S+FX
```

```
      GOTO (4,5),I
4     S=S+FX
      I=2
      GOTO 3
5     I=1
3     X=X+DX
6     CONTINUE
      G=(F(-5.0)+S+S+F(BETA))*DX/3.0
      RETURN
      END
```

PCON.FOR

```
C
C  PROGRAM TO DETERMINE OPTIMUM INSPECTION FREQUENCY FOR
C  CONCRETE FACILITIES BASED ON EXPECTED ANNUAL COSTS
C
      INTEGER AGE
      REAL LEV1CST,LEV2CST
 901  DO 14 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                              '
  14  CONTINUE
      DO 24 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
     +    '
  24  CONTINUE
      CALL CUP(3,17)
      WRITE(*,*)'                 CONCRETE'
      CALL CUP(4,17)
      WRITE(*,*)'     SELECT ONE OF THE FOLLOWING OPTIONS'
      CALL CUP(5,17)
      WRITE(*,*)'    -------------------------------------'
      CALL CUP(10,20)
      WRITE(*,*)' 1)  REVIEW DETERIORATION COEFFICIENTS'
      CALL CUP(11,20)
      WRITE(*,*)' 2)  REVIEW INSPECTION COST DATA'
      CALL CUP(12,20)
      WRITE(*,*)' 3)  REVIEW REPAIR COST DATA'
      CALL CUP(13,20)
      WRITE(*,*)' 4)  REVIEW FAILURE COST DATA'
      CALL CUP(14,20)
      WRITE(*,*)' 5)  REVIEW SAMPLING CRITERIA'
      CALL CUP(15,20)
      WRITE(*,*)' 6)  GENERATE INSPECTION FREQUENCIES'
      CALL CUP(18,30)
      WRITE(*,*)'SELECTION: ___'
      CALL CUP(18,43)
      READ(*,*) ISELECT
      IF(ISELECT.EQ.1) GOTO 1001
      IF(ISELECT.EQ.2) GOTO 2001
      IF(ISELECT.EQ.3) GOTO 3001
      IF(ISELECT.EQ.4) GOTO 4001
      IF(ISELECT.EQ.5) GOTO 5001
      IF(ISELECT.EQ.6) GOTO 6001
C
C  MODIFY DETERIORATION RATE COEFFICIENTS
C
 1001 OPEN(28,FILE='CONCOEF',STATUS='OLD')
      READ(28,301) RATEA,RATEB
      DO 15 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                              '
  15  CONTINUE
      DO 25 I=9,22
      CALL CUP(I,10)
```

```
      WRITE(*,*)'
 25   CONTINUE
      CALL CUP(4,17)
      WRITE(*,*)'          DETERIORATION COEFFICIENT'
      CALL CUP(5,17)
      WRITE(*,*)'         ---------------------------'
      CALL CUP(11,14)
      WRITE(*,*)'THE CURRENT INTERCEPT COEF. IS:'
      CALL CUP(11,52)
      WRITE(*,'(F8.6)') RATEA
      CALL CUP(13,14)
      WRITE(*,*)'THE CURRENT MEAN COEF. IS:'
      CALL CUP(13,52)
      WRITE(*,'(F8.6)') RATEB
 777  CALL CUP(17,14)
      WRITE(*,*)' DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,58)
      READ(*,'(A1)',ERR=777)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 231
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 1001
 231  CALL CUP(17,10)
      WRITE(*,*)'
      CALL CUP(17,14)
      WRITE(*,*)'ENTER THE NEW INTERCEPT COEFFICIENT'
      CALL CUP(17,51)
      WRITE(*,*)'__________'
      CALL CUP(17,52)
      READ(*,*) RATEA1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER THE NEW MEAN COEFFICIENT'
      CALL CUP(19,51)
      WRITE(*,*)'__________'
      CALL CUP(19,52)
      READ(*,*) RATEB1
      REWIND(28)
      WRITE(28,301) RATEA1,RATEB1
 301  FORMAT(2F8.6)
      CLOSE(28,STATUS='KEEP')
      GOTO 901
C
C  MODIFY INSPECTION COSTS
C
 2001 OPEN(29,FILE='CINSPECT',STATUS='OLD')
      READ(29,302) LEV1CST,LEV2CST
      DO 16 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'
  16  CONTINUE
      DO 26 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'
  26  CONTINUE
      CALL CUP(4,19)
      WRITE(*,*)'                INSPECTION COSTS'
```

```
      CALL CUP(5,19)
      WRITE(*,*)'                 ------------------'
      CALL CUP(11,14)
      WRITE(*,*)'LEVEL 1 INSPECTION COST: $'
      CALL CUP(11,52)
      WRITE(*,'(F8.2)') LEV1CST
      CALL CUP(13,14)
      WRITE(*,*)'LEVEL 2 OR 3 INSPECTION COST: $'
      CALL CUP(13,52)
      WRITE(*,'(F8.2)') LEV2CST
  778 CALL CUP(17,14)
      WRITE(*,*)' DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,58)
      READ(*,'(A1)',ERR=778)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 241
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 2001
 241  CALL CUP(17,10)
      WRITE(*,*)'                                                    '
      CALL CUP(17,14)
      WRITE(*,*)'ENTER LEVEL 1 INSPECTION COST: $'
      CALL CUP(17,54)
      WRITE(*,*)'_________'
      CALL CUP(17,55)
      READ(*,*) LEV1CST1
      CALL CUP(19,14)
      WRITE(*,*)'ENTER LEVEL 2 OR 3 INSPECTION COST: $'
      CALL CUP(19,54)
      WRITE(*,*)'_________'
      CALL CUP(19,55)
      READ(*,*) LEV2CST1
      REWIND(29)
      WRITE(29,302) LEV1CST1,LEV2CST1
 302  FORMAT(2F8.2)
      CLOSE(29,STATUS='KEEP')
      GOTO 901
C
C  MODIFY REPAIR COSTS
C
 3001 OPEN(37,FILE='CREPAIR',STATUS='OLD')
      READ(37,303) CSTREP
      DO 17 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                                  '
  17  CONTINUE
      DO 27 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'                                                         '
  27  CONTINUE
      CALL CUP(4,20)
      WRITE(*,*)'              REPAIR COSTS'
      CALL CUP(5,20)
      WRITE(*,*)'              --------------'
      CALL CUP(11,14)
      WRITE(*,*)'CURRENT REPAIR COST: $'
```

```
      CALL CUP(11,52)
      WRITE(*,'(F8.2)') CSTREP
  779 CALL CUP(17,14)
      WRITE(*,*)' DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(17,58)
      READ(*,'(A1)',ERR=779)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 251
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 3001
 251  CALL CUP(17,10)
      WRITE(*,*)'                                                  '
      CALL CUP(17,14)
      WRITE(*,*)'ENTER THE REPAIR COST: $'
      CALL CUP(17,52)
      WRITE(*,*)'_________'
      CALL CUP(17,53)
      READ(*,*) CSTREP1
      REWIND(37)
      WRITE(37,303) CSTREP1
 303  FORMAT(F8.2)
      CLOSE(37,STATUS='KEEP')
      GOTO 901
C
C  MODIFY FAILURE COSTS
C
 4001 OPEN(38,FILE='CFAILURE',STATUS='OLD')
      READ(38,304) CSTREPL,CSTLOST,CSTLIFE,CSTUSE
      DO 18 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                              '
  18  CONTINUE
      DO 28 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'                                                    '
  28  CONTINUE
      CALL CUP(4,20)
      WRITE(*,*)'              FAILURE COSTS'
      CALL CUP(5,20)
      WRITE(*,*)'             ---------------'
      CALL CUP(11,14)
      WRITE(*,*)'CURRENT REPLACEMENT COST: $'
      CALL CUP(11,54)
      WRITE(*,'(F12.2)') CSTREPL
      CALL CUP(12,14)
      WRITE(*,*)'CURRENT COST OF LOST EQUIPMENT: $'
      CALL CUP(12,54)
      WRITE(*,'(F12.2)') CSTLOST
      CALL CUP(13,14)
      WRITE(*,*)'CURRENT COST OF LOST LIFE: $'
      CALL CUP(13,54)
      WRITE(*,'(F12.2)') CSTLIFE
      CALL CUP(14,14)
      WRITE(*,*)'CURRENT COST OF LOSS OF FACILITY USE: $'
      CALL CUP(14,54)
      WRITE(*,'(F12.2)') CSTUSE
```

```
 780 CALL CUP(17,14)
     WRITE(*,*)'    DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
     CALL CUP(17,61)
     READ(*,'(A1)',ERR=780)ANS1
     IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 261
     IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
     GOTO 4001
 261 CALL CUP(17,10)
     WRITE(*,*)'                                                            '
     CALL CUP(17,14)
     WRITE(*,*)'ENTER THE REPLACEMENT COST: $'
     CALL CUP(17,59)
     WRITE(*,*)'_________'
     CALL CUP(17,60)
     READ(*,*) CSTREPL1
     CALL CUP(18,14)
     WRITE(*,*)'ENTER THE EQUIPMENT COST: $'
     CALL CUP(18,59)
     WRITE(*,*)'_________'
     CALL CUP(18,60)
     READ(*,*) CSTLOST1
     CALL CUP(19,14)
     WRITE(*,*)'ENTER THE COST OF LOST LIFE: $'
     CALL CUP(19,59)
     WRITE(*,*)'_________'
     CALL CUP(19,60)
     READ(*,*) CSTLIFE1
     CALL CUP(20,14)
     WRITE(*,*)'ENTER THE COST OF FACILITY USE: $'
     CALL CUP(20,59)
     WRITE(*,*)'_________'
     CALL CUP(20,60)
     READ(*,*) CSTUSE1
     REWIND(38)
     WRITE(38,304) CSTREPL1,CSTLOST1,CSTLIFE1,CSTUSE1
 304 FORMAT(4F12.2)
     CLOSE(38,STATUS='KEEP')
     GOTO 901
C
C  MODIFY SAMPLING CRITERIA
C
5001 OPEN(44,FILE='CSAMPLE',STATUS='OLD')
     READ(44,607) CONLEV,DESACC,APROP
     DO 73 I=3,5
     CALL CUP(I,17)
     WRITE(*,*)'                                                     '
  73 CONTINUE
     DO 74 I=9,22
     CALL CUP(I,10)
     WRITE(*,*)'                                                            '
 74  CONTINUE
     CALL CUP(4,19)
     WRITE(*,*)'              SAMPLING CRITERIA'
     CALL CUP(5,19)
     WRITE(*,*)'             ------------------'
```

```
      CALL CUP(10,9)
      WRITE(*,*)'     CURRENT CONFIDENCE LEVEL'
      CALL CUP(10,52)
      WRITE(*,'(F5.3)') CONLEV
      CALL CUP(11,9)
      WRITE(*,*)'     CURRENT DESIRED ACCURACY'
      CALL CUP(11,52)
      WRITE(*,'(F5.3)') DESACC
      CALL CUP(12,9)
      WRITE(*,*)'     EXPECTED ATTRIBUTE PROPORTION'
      CALL CUP(12,52)
      WRITE(*,'(F5.3)') APROP
 679  CALL CUP(14,10)
      WRITE(*,*)'    DO YOU WISH TO CHANGE THESE VALUES (Y/N)?___'
      CALL CUP(14,57)
      READ(*,'(A1)',ERR=679)ANS1
      IF(ANS1.EQ.'Y'.OR.ANS1.EQ.'y')GOTO 371
      IF(ANS1.EQ.'N'.OR.ANS1.EQ.'n')GOTO 901
      GOTO 5001
 371  CALL CUP(14,10)
      WRITE(*,*)'                                                    '
      CALL CUP(14,14)
      WRITE(*,*)'ENTER NEW CONFIDENCE LEVEL'
      CALL CUP(15,14)
      WRITE(*,*)' (0.90, 0.95, 0.98 OR 0.99)'
      CALL CUP(15,53)
      WRITE(*,*)'__________'
      CALL CUP(15,54)
      READ(*,*) CONLEV1
      CALL CUP(16,14)
      WRITE(*,*)'ENTER DESIRED ACCURACY'
      CALL CUP(17,14)
      WRITE(*,*)'(0.01 TO 0.20)'
      CALL CUP(17,53)
      WRITE(*,*)'__________'
      CALL CUP(17,54)
      READ(*,*) DESACC1
      CALL CUP(18,14)
      WRITE(*,*)'ENTER EXPECTED ATTRIBUTE PROPORTION'
      CALL CUP(19,14)
      WRITE(*,*)'(0.01-0.99)'
      CALL CUP(19,53)
      WRITE(*,*)'__________'
      CALL CUP(19,54)
      READ(*,*) APROP
      REWIND(44)
      WRITE(44,607) CONLEV1,DESACC1,APROP
 607  FORMAT(3F5.3)
      CLOSE(44,STATUS='KEEP')
      GOTO 901
C
C  OUTPUT OPTION SCREEN
C
 6001 IKI=7
      IDO=2
```

```
111  DO 181 I=3,5
     CALL CUP(I,17)
     WRITE(*,*)'                                                        '
181  CONTINUE
     DO 19 J=9,20
     CALL CUP(J,16)
     WRITE(*,*)'                                                          '
 19  CONTINUE
     CALL CUP(4,17)
     WRITE(*,*)'    INSPECTION FREQUENCIES FOR CONCRETE PILES'
     CALL CUP(5,17)
     WRITE(*,*)'   --------------------------------------------'
     CALL CUP(9,10)
     WRITE(*,*)'                     OUTPUT OPTIONS    '
     CALL CUP(10,10)
     WRITE(*,*)'                    ----------------   '
     CALL CUP(12,10)
     WRITE(*,*)'                  1) OUTPUT TO SCREEN'
     CALL CUP(13,10)
     WRITE(*,*)'                  2) OUTPUT TO PRINTER'
     CALL CUP(14,10)
     WRITE(*,*)'                  3) OUTPUT TO BOTH  '
 222 CALL CUP(16,10)
     WRITE(*,*)'                        OPTION:___        '
     IJK=0
     CALL CUP(16,43)
     READ(*,'(I1)',ERR=222)IOP
     IF(IOP.LT.1.OR.IOP.GT.3)GOTO 222
     IF(IOP.EQ.2.OR.IOP.EQ.3)THEN
     CALL CUP(18,10)
     WRITE(*,*)'    *** CHECK TO SEE IF PRINTER IS PROPERLY CONNECTED *
    +**'
     CALL CUP(19,10)
     WRITE(*,*)'       IF PRINTER IS NOT CONNECTED PROGRAM WILL ABORT'
     DO 225 IJ=1,7000
     IDO=IDO/IJ*3
225  CONTINUE
     CALL CUP(18,10)
     WRITE(*,*)'
    +  '
     CALL CUP(19,10)
     WRITE(*,*)'                                                       '
 133 CALL CUP(18,10)
     WRITE(*,*)'          IS THE PRINTER PROPERLY CONNECTED (Y/N)?___  '
     CALL CUP(18,62)
     READ(*,'(A1)',ERR=133)ANS
     IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')GOTO 131
     IF(ANS.EQ.'N'.OR.ANS.EQ.'n')GOTO 223
     GOTO 133
 223 CALL CUP(19,10)
     WRITE(*,*)'         *** NO PRINTER IS CONNECTED TO SYSTEM ***'
     CALL CUP(20,1)
     PAUSE
     GOTO 111
     ENDIF
```

```
C
  131 DO 57 I=3,5
      CALL CUP(I,17)
      WRITE(*,*)'                                                              '
  57  CONTINUE
      DO 58 I=9,22
      CALL CUP(I,10)
      WRITE(*,*)'                                                              '
  58  CONTINUE
C
C  DATA INPUT SCREEN
C
      CALL CUP(4,29)
      WRITE(*,*)'ENTER THE FOLLOWING DATA'
      CALL CUP(5,29)
      WRITE(*,*)'------------------------'
      CALL CUP(13,16)
      WRITE(*,'(A)')'AGE OF PIER'
      CALL CUP(15,16)
      WRITE(*,'(A)')'NUMBER OF PILES IN PIER'
      CALL CUP(17,16)
      WRITE(*,'(A)')'AGE AT WHICH DETERIORATION BEGINS'
      CALL CUP(13,55)
      WRITE(*,*)'______'
      CALL CUP(13,56)
      READ(*,'(I4)') AGE
      CALL CUP(15,55)
      WRITE(*,*)'______'
      CALL CUP(15,56)
      READ(*,'(I4)') NUM
      CALL CUP(17,55)
      WRITE(*,*)'______'
      CALL CUP(17,56)
      READ(*,'(I4)') NUMAGE
C
C  OPEN EXISTING DATA INPUT FILES AND CREATE OUTPUT HEADING
C
C
      CALL ED
      OPEN(28,FILE='CONCOEF',STATUS='OLD')
      OPEN(29,FILE='CINSPECT',STATUS='OLD')
      OPEN(37,FILE='CREPAIR',STATUS='OLD')
      OPEN(38,FILE='CFAILURE',STATUS='OLD')
      OPEN(44,FILE='CSAMPLE',STATUS='OLD')
      READ(28,'(2F8.6)') RATEA,RATEB
      READ(29,'(2F8.2)') LEV1CST,LEV2CST
      READ(37,'(F8.2)') CSTFIX
      READ(38,'(4F12.2)') CSTREPL,CSTLOST,CSTLIFE,CSTUSE
      READ(44,'(3F5.3)') CONLEV,DESACC,APROP
      CALL CUP(3,0)
      IF(IOP.EQ.1.OR.IOP.EQ.3)THEN
      WRITE(*,'(A)')'                           EXPECTED ANNUAL COSTS'
      WRITE(*,*)
      WRITE(*,'(A)')'    INSPECTION        INSPECTION        REPAIR
     + FAILURE          TOTAL'
```

```
      CALL CUP(6,0)
      WRITE(*,'(A)')'      PERIOD             COST              COST
     +  COST             COST'
      CALL CUP(7,0)
      WRITE(*,'(A)')'   -----------------------------------------------
     +-----------------------'
      ENDIF
C
C  PRODUCE HARD COPY OF INPUT VALUES
C
      IF(IOP.EQ.2.OR.IOP.EQ.3)THEN
      OPEN(9,FILE='LPT1')
      WRITE(9,*)
      WRITE(9,*)
      WRITE(9,'(28X,A20)')'CONCRETE INPUT VALUES'
      WRITE(9,*)
      WRITE(9,'(5X,A50,F16.6)')'INTERCEPT COEFFICIENT:
     +          ',RATEA
      WRITE(9,'(5X,A50,F16.6)')'MEAN COEFFICIENT:
     +          ',RATEB
      WRITE(9,'(5X,A50,F12.2)')'LEVEL 1 INSPECTION COST:
     +          ',LEV1CST
      WRITE(9,'(5X,A50,F12.2)')'LEVEL 2 OR 3 INSPECTION COST:
     +          ',LEV2CST
      WRITE(9,'(5X,A50,F12.2)')'REPAIR COST:
     +          ',CSTFIX
      WRITE(9,'(5X,A50,F12.2)')'REPLACEMENT COST:
     +          ',CSTREPL
      WRITE(9,'(5X,A50,F12.2)')'EQUIPMENT LOSS COST:
     +          ',CSTLOST
      WRITE(9,'(5X,A50,F12.2)')'LOSS OF LIFE COST:
     +          ',CSTLIFE
      WRITE(9,'(5X,A50,F12.2)')'LOSS OF USE COST:
     +          ',CSTUSE
      WRITE(9,'(5X,A50,F12.2)')'CONFIDENCE LEVEL:
     +          ',CONLEV
      WRITE(9,'(5X,A50,F12.2)')'DESIRED ACCURACY:
     +          ',DESACC
      WRITE(9,'(5X,A50,F12.2)')'EXPECTED ATTRIBUTE PROPORTION:
     +          ',APROP
      WRITE(9,'(5X,A55,I4)')'AGE OF PIER:
     +               ',AGE
      WRITE(9,'(5X,A55,I4)')'NUMBER OF PILES IN PIER:
     +               ',NUM
      WRITE(9,'(5X,A55,I4)')'AGE AT WHICH DETERIORATION BEGINS:
     +               ',NUMAGE
      WRITE(9,*)
      WRITE(9,*)
      WRITE(9,'(27X,A22)')'EXPECTED ANNUAL COSTS'
      WRITE(9,*)
      WRITE(9,*)'INSPECTION     INSPECTION        REPAIR        FAILURE
     +        TOTAL'
      WRITE(9,*)'  PERIOD          COST              COST          COST
     +        COST'
      WRITE(9,*)'-----------------------------------------------------------
```

```
     +-------------'
        ENDIF
C
C  BEGIN LOOP TO CALCULATE DAMAGE PROBABILITIES FOR DIFFERENT
C  AGE
C
        LKL=9
        DO 40 J5=1,25
        IF(AGE.LT.NUMAGE) THEN
         PROBDAM=0.0
        ENDIF
        IF(AGE.GE.NUMAGE) THEN
         Y1=RATEA+(RATEB*FLOAT(J5))
         X=(1-Y1)
         Y=EXP(X)
         Y2=(1+Y)
         PROBDAM=Y/Y2
        ENDIF
        DAMAGE=FLOAT(NUM)*PROBDAM
        NUMDAM=NINT(DAMAGE)
C
C  DETERMINES NUMBER OF PILES FOR LEVEL 2 OR 3 INSPECTION SAMPLE
C
          IF(CONLEV.EQ.0.90) Z=1.645
          IF(CONLEV.EQ.0.95) Z=1.96
          IF(CONLEV.EQ.0.98) Z=2.326
          IF(CONLEV.EQ.0.99) Z=2.576
          SAM1=(DESACC**2)/((Z**2)*APROP*(1-APROP))
          SAM2=1/FLOAT(NUM)
          SAM=1/(SAM1+SAM2)
          IF(SAM.LT.30.0) SAM=30.0
C
C  CALCULATES COSTS
C
          NUM1=NINT(SAM)
          NUM2=NUM-NUM1
          CICOST=((FLOAT(NUM2)*LEV1CST)+(FLOAT(NUM1)*LEV2CST))/FLOAT(J5)
          CRCOST=(FLOAT(NUMDAM)*CSTFIX)/FLOAT(J5)
          CFCOST=((FLOAT(NUMDAM)*0.03)*CSTREPL)+CSTLOST+CSTLIFE+CSTUSE
          TOTCOST=CICOST+CRCOST+CFCOST
C
C  CLEARS SCREENS
C
        LKL=LKL+1
        IF(J5.EQ.11.OR.J5.EQ.21.OR.J5.EQ.31) LKL=9
        IF(LKL .EQ. 9)THEN
         CALL CUP(22,22)
         WRITE(*,*)'PRESS THE <RETURN> KEY TO CONTINUE'
         CALL CUP(22,57)
         READ(*,'(A1)')COOL
         DO 666 JKJ=9,22
         CALL CUP(JKJ,0)
         WRITE(*,*)'
     +                                '
  666 CONTINUE
```

```
      ENDIF
C
C  OUTPUT TO SCREEN
C
      CALL CUP(LKL,0)
      IF(IOP.EQ.1.OR.IOP.EQ.3) THEN
      WRITE(*,99) J5,CICOST,CRCOST,CFCOST,TOTCOST
 99   FORMAT(8X,I2,9X,F12.0,2X,F12.0,2X,F12.0,3X,F12.0)
      ENDIF
C
C  HARD COPY OUTPUT
C
      IF(IOP.EQ.2.OR.IOP.EQ.3) THEN
      WRITE(9,98) J5,CICOST,CRCOST,CFCOST,TOTCOST
 98   FORMAT(5X,I2,7X,F12.0,3X,F12.0,3X,F12.0,2X,F12.0)
      ENDIF
C
C  INCREMENT AGE
C
      AGE=AGE+1
 40   CONTINUE
      CALL CUP(20,22)
      WRITE(*,*)'PRESS THE <RETURN> KEY TO CONTINUE'
      CALL CUP(20,57)
      READ(*,'(A1)')COOL
      CALL ED
      END
```

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BARTZ, J Santa Barbara, CA
BESIER, RF CE, Old Saybrook, CT
BRADFORD ROOFING T. Ryan, Billings, MT
BULLOCK, TE La Canada, CA
CHAO, JC Houston, TX
DE PALMA, J R Picayune, MS

DOBROWOLSKI, J.A. Altadena, CA
GRAY, K.O. Falls Church, VA
HIRSCH & CO E. Hirsch San Diego, CA
LAYTON, J.A. Redmond, WA
MARINE RESOURCES DEV FOUNDATION N.E. Monney, Annapolis, MD
PAULI, D.C. Silver Spring, MD
PETERSEN, CAPT N.W. Pleasanton, CA
PRESNELL ASSOC. INC D.G. Presnell Jr Louisville, KY
QUIRK, J. Panama City, FL
SETHNESS, D. Round Rock, TX
SPIELVOGEL, L. Wyncote, PA
STEVENS, J.W. Long Beach, MS
MERMEL, T.W. Washington, DC
TEDESKO, A. Bronxville, NY

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